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August 2, 2010

Mr. Kenneth Bardo - LU-9J
U.S. EPA Region V
Corrective Action Section
77 West Jackson Boulevard
Chicago, IL 60604-3507

VIA FEDEX

Re: PCB Groundwater Quality Assessment Program
Evaluation of 3Q08 - 2Q10 Data
Solutia Inc., W. G. Krummrich Plant, Sauget, IL

Dear Mr. Bardo:

As noted when the 2nd Quarter 2010 Data Report for the subject program was submitted July 22, enclosed please find a report evaluating all of the PCB groundwater monitoring data collected from 3rd quarter 2008 through 2nd quarter 2010, i.e., since the February 2008 Final Decision, and making recommendations for changes going forward. Reiterating those recommended changes from the enclosed report:

- reduce sampling frequency from quarterly to semiannually during the first and third quarters of each year; and

- discontinue sampling of wells PMAMW01S, PMAMW02S, and PMAMW05M.

I'd appreciate your prompt response because the 3rd quarter 2010 sampling is scheduled to take place this month.

If you have any questions or comments regarding this report, please contact me at (314) 674-3312 or gmrina@solutia.com

Sincerely,

Gerald M. Rinaldi
Manager, Remediation Services

Enclosure

cc: Distribution List

DISTRIBUTION LIST

PCB Groundwater Quality Assessment Program
Evaluation of 3Q08 - 2Q10 Data
Solutia Inc., W. G. Krummrich Plant, Sauget, IL

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URS

Technical Memorandum

Date: July 30, 2010

To: Jerry Rinaldi - Solutia Inc.

cc: Bob Billman – URS Corporation, St. Louis

From: Wade A. Narin van Court, P.E. and Paul Stanley – URS Corporation, Hallowell, Maine

Subject: **2nd Quarter 2010 Evaluation of the PCB Groundwater Quality Assessment Program at the W. G. Krummrich Facility**

1.0 INTRODUCTION

The Former PCB Manufacturing Area (hereafter referred to as "the Site") is an area on the Solutia Inc. (Solutia) W. G. Krummrich Facility (hereafter referred to as "the Facility") located in Sauget, Illinois. The U.S. Environmental Protection Agency (USEPA) issued a Final Decision on February 26, 2008, that specified the preparation and submission of an PCB Groundwater Quality Assessment Program Work Plan (Work Plan) for the Site and, upon approval, implementation of that plan. The Work Plan (submitted April 11, 2008, and approved April 21, 2008) called for monitoring to determine PCBs in groundwater at and downgradient of the Site. The assessment program had to be capable of monitoring the Shallow, Middle and Deep Hydrologic Units (SHU, MHU and DHU, respectively).

The Work Plan was developed by Solutia to meet the requirements of the Final Decision. The activities implemented under the Work Plan include collecting quarterly groundwater samples from 10 wells, which are screened in the SHU (S), MHU (M), and DHU (D). The monitoring wells sampled at the Site were: PMA-MW-1S, PMA-MW-1M, PMA-MW-2S, PMA-MW-2M, PMA-MW-3M, PMA-MW-3S, PMA-MW-4D, PMA-MW-4S, PMA-MW-5M, and PMA-MW-6D. Monitoring well PMA-MW-4S, located in the source area, was only sampled in the first and second quarters of 2010 (1Q10 and 2Q10) when dense non-aqueous-phase liquid (DNAPL) was not present. The locations of these monitoring wells are shown in **Figure 1**. During the monitoring rounds, samples were obtained using low-flow sampling techniques. Indicator parameters monitored during purging of the wells using a flow cell include pH, temperature, turbidity, specific conductance, oxidation/reduction potential (ORP), and dissolved oxygen. Constituents of interest (COI) at the Site were polychlorinated biphenyl (PCB) homologs, which are mixtures of different PCB congeners. In particular, groundwater samples collected during the sampling events were analyzed for the following PCB homologs: monochlorobiphenyl, dichlorobiphenyl, trichlorobiphenyl, tetrachlorobiphenyl, pentachlorobiphenyl, hexachlorobiphenyl, heptachlorobiphenyl, octachlorobiphenyl, nonachlorobiphenyl and decachlorobiphenyl.

Throughout the past eight quarters, PCBs were not detected in monitoring wells PMA-MW-1S, PMA-MW-2S, and PMA-MW-5M. Furthermore, only monochlorobiphenyl and dichlorobiphenyl were detected in the other monitoring wells during more than one sampling round. Therefore, this evaluation was primarily focused on these two specific homologs. Monochlorobiphenyl was detected in the following monitoring wells: PMA-MW-1M, PMA-MW-2M, PMA-MW-3M, PMA-MW-3S, and PMA-MW-6D, as well as PMA-MW-4D and PMA-MW-4S in the source area. Additionally, dichlorobiphenyl was only detected in monitoring wells PMA-MW-3S and PMA-MW-4D in more than one monitoring round.

As part of the Work Plan, statistical analyses of potential trends in the COI concentrations were to be performed to determine the plume stability by the following methods:

1. Mann-Kendall trend analysis,

2. Mann-Whitney U Test, and
3. Linear regression analysis (if allowed by the data distribution).

These analyses are discussed and the results are presented in **Section 3.0** of this report, following a brief review of the relevant background information at the Site in **Section 2.0**. The conclusions of the data review and statistical analyses are presented in **Section 4.0**. Recommendations for future monitoring are presented in **Section 5.0**.

2.0 RELEVANT BACKGROUND INFORMATION

A number of investigations had been performed to characterize the Facility and its groundwater characteristics prior to starting the current Work Plan at the Site. In particular, these investigations obtained data used to determine the aquifer characteristics and existing hydrogeologic conditions. The existing information relevant to the evaluation of plume stability is discussed in the following sections.

2.1 AQUIFER CHARACTERISTICS

Aquifer characteristics need to be considered when evaluating plume stability. For example, groundwater velocities, which are determined by hydraulic properties, e.g., hydraulic conductivity and effective porosity, are used to calculate attenuation rate constants, as described later in this memorandum.

Based on the description from the Technology Selection Report (Booz Allen Hamilton, 2007), soils beneath the Site consist of poorly-sorted fine and medium sands with traces of silt and gravel and occasional clay lenses. In the Site vicinity, depth to bedrock is approximately 110 feet below the ground surface (bgs), and approximately 140 feet below the crest of 30-foot high levees along the banks of the Mississippi River.

Three distinct hydrologic units have been identified in the unconsolidated soil which, downward from the ground surface, are the shallow hydrologic unit (SHU), the medium hydrologic unit (MHU) and the deep hydrologic unit (DHU). The SHU is approximately 30 feet thick; the MHU and DHU are each approximately 40 feet thick and are similar in composition. Based upon the similarity in grain-size composition, aquifer properties for SHU, MHU and DHU were assumed to be similar for this evaluation. The aquifer properties used in the analyses are summarized in **Table 1**.

Table 1: Typical Soil Properties	
Soil Property	**Value Used in MNA Evaluation Analyses** (Source: URS, 2008 unless noted)
Hydraulic Conductivity (K)	1.75 x 10^{-2} centimeters per second (cm/sec)
Hydraulic Gradient (i)	0.0014 feet/foot
Bulk Density (ρ_b, dry unit weight)	118.3 pounds per cubic foot (1,895 kilograms per cubic meter)
Porosity (n)	28.8%
Effective Porosity (n_e)	20% (Env. Tech., 1997)
Fraction Organic Carbon (f_{oc})	0.0016

2.2 Site Hydrogeology

Hydrogeologic conditions are also an important consideration when evaluating PCBs in groundwater. Site data were reviewed to develop an understanding of the hydrogeologic conditions that could influence the interpretation of plume. Relevant hydrogeologic conditions at the Site at briefly discussed below.

An important hydrologic feature that affects groundwater flow beneath the Site is the Mississippi River, which is interpreted to typically be the groundwater discharge point for all three hydrologic units. However, the groundwater that discharges into the Mississippi River is not adversely affecting water quality, based on the results of past and ongoing surface water and sediment sampling.

Since summer 2006[1], the stage of the Mississippi River downgradient of the Site has varied over 30 feet, from an approximate elevation of 380 feet mean sea level (MSL) to 410 feet MSL. During periods when the stage is raised (i.e., generally above elevation 390 feet MSL), it has been observed to be higher than groundwater levels in the MHU and/or DHU immediately adjacent to the river, as presumably in the SHU. As such, higher water levels may mobilize COI from the vadose zone at the Site into groundwater. However the monitoring wells in the former PCB Manufacturing Area are further from the river and not as affected by the river stage as other Site wells.

Another consideration that may affect the transport of COI from the Site is the Groundwater Migration Control System (GMCS) installed at Sauget Superfund Site R, which is adjacent to the Mississippi River and south to southwest of the Site. The GMCS consists of a three-sided vertical barrier and groundwater extraction wells. The barrier is keyed into the underlying bedrock and open to the west, so groundwater from impacted areas to the east are intercepted while the amount of river water intercepted by the extraction wells is minimized. During normal river conditions, the extraction pumps operate to create a groundwater gradient that captures groundwater flow into the GMCS from the east.

3.0 ASSESSMENT OF TRENDS AND PLUME STABILITY

To assess trends and plume stability, URS reviewed analytical data for COI in the former PCB Manufacturing Area monitoring wells that was obtained quarterly over the past two years (i.e., eight sets of data). To see if COI concentrations were increasing or decreasing at the Site, this review included: 1) plotting the change in concentration over time in each well; and 2) assessing the concentration trends by performing a statistical analysis of the COI analytical data.

3.1 Plots of Concentrations

Plots of concentrations of mono- and dichlorobiphenyl were developed for each well, as appropriate, to evaluate concentration changes for these COI over time. These plots were also reviewed to determine the extent of PCBs in groundwater downgradient of the Site. In the monitoring wells where PCBs were detected, the total concentrations did not exceed 0.5 µg/L in monitoring wells PMA-MW-1M and PMA-MW-6D. The monitoring wells where the total PCB concentration exceeded 0.5 µg/L in 2Q10 are summarized in **Table 2**. Supporting information is presented in **Attachment A**.

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[1] The first quarterly event for the PCB Mobility and Migration Investigation conducted at the Facility occurred in June 2006.

Table 2: Wells with Total PCB Concentrations above 0.5 µg/L (Based on Data from 2nd Quarter 2010)		
Well	**Total PCB (µg/L)***	**Comments**
Downgradient Monitoring Wells		
PMA-MW-2M	3.9	Approximately 250 feet downgradient
PMA-MW-3S	0.63	Approximately 250 feet downgradient
PMA-MW-3M	0.82	Approximately 250 feet downgradient
Source Area Monitoring Wells		
PMA-MW-4D	0.72	At depth below source area
PMA-MW-4S	2,131**	In source area

* Total PCB concentration is the sum of the concentrations of all homologs that were detected. Non-detect values were not included in determining the total concentration.

** Elevated concentration due to suspected presence of DNAPL.

Additionally, groundwater (potentiometric) elevations observed in the wells were overlaid on the COI concentration plots. Review of these plots indicates that increased COI concentrations generally appeared to coincide with increased groundwater elevations. In other words, the COI concentrations demonstrated seasonal variations, as is discussed in following sections. This was likely due to the elevated groundwater conditions allowing additional PCBs that were adsorbed in the unsaturated zone to go into solution, and so increased the concentrations of the PCB homologs.

3.2 STATISTICAL ANALYSES

The statistical analyses included Mann-Kendall Test, Mann-Whitney U Test, Pooled Variance Student's T-Test, and linear regression. These analysis methods and results of the analyses are discussed below.

3.2.1 Mann-Kendall Analysis

The Work Plan stated that the sample results were to be analyzed to determine if any statistically significant changes (i.e., concentration increases or decreases) occurred over time. This analysis was performed using the non-parametric Mann-Kendall Test, combined with the coefficient of variation (CV) test, to evaluate the significance of trends of COI in groundwater at the Site. The Mann-Kendall Test is considered to be appropriate for evaluating trends in the data for the following reasons (USEPA, 2009):

- This test is designed to handle data that are non-parametric (i.e., do not exhibit a specific distribution such as normal or log normal);
- Data set can contain data collected at irregularly spaced intervals in time; and
- Data set can contain elevated (outlier) values compared to the average or non-detect results.

The Mann-Kendall Test was performed using the spreadsheet provided by the State of Wisconsin Department of Natural Resources Remediation and Redevelopment Program (WIDNR Form 4400-215, dated February 2001). The WIDNR spreadsheet evaluates trends in data over time at the 80% and 90% confidence levels. If no trend exists at the 80% confidence level, the spreadsheet will evaluate the stability of the data. The WIDNR spreadsheet was revised by URS to also evaluate trends at the 95 % confidence level.

Performing the Mann-Kendall Test with the WIDNR spreadsheet will provide one of several different trend and stability results for a given data set. These results, as well as what they mean, are as follows:

1. Trend Results:

   - Increasing – a sufficient number of data points are greater than the previous data points, so the Mann-Kendall Statistic (S) is greater than the absolute value of the critical Mann-Kendall Statistic (S_{cr}) for the given confidence level.

   - Decreasing – a sufficient number of data points are less than the previous data points, so the Mann-Kendall Statistic (S) is less than the critical Mann-Kendall Statistic (S_{cr}) for the given confidence level.

   - No Trend – does not meet the criteria for increasing or decreasing trends.

   - n<4 – an insufficient number of data points that are considered to be valid to perform the Mann-Kendall Test (i.e., less than 4 valid data points), so data could not be analyzed.

2. Stability Results:

   - Stable – A trend could not be determined at the 80% confidence level and the covariance is less than 1.0.

   - Non-Stable – A trend could not be determined at the 80% confidence level and the covariance is greater than or equal to 1.0.

   - NA – Not Analyzed; stability could not be determined at the 80% confidence level because the Mann-Kendall Statistic (S) was greater than the number of events in the analysis.

   - n<4 – an insufficient number of data points that are considered to be valid to perform the Mann-Kendall Test (i.e., less than 4 valid data points), so data could not be analyzed.

The Mann-Kendall Test is not valid for unadjusted data that exhibits seasonal behavior (i.e., data that is not seasonally consistent). Seasonal behavior of the data (i.e., from 3Q08 through 2Q10) from the wells were evaluated in two ways. First, as noted above, the potentiometric contours for the Facility are affected by seasonal water level changes, which result in seasonal variations in the COI concentrations. Second, COI concentrations and groundwater elevations measured during each sampling event were plotted versus time. For the PMA monitoring wells, concentrations of COI and groundwater elevations tended to exhibit seasonal effects. Specifically, the data from six of the eight quarters, 3Q08 and 2Q09 through 2Q10, were determined to be seasonally consistent, and data from 4Q08 and 1Q09 was not considered to be consistent. Therefore, six monitoring events were considered to provide seasonally valid data that were used for the Mann-Kendall Test analysis.

The results of the trend analyses for the COI in each monitoring well are summarized below in **Table 3**, below, and supporting data and analyses are presented in **Attachment B**.

Table 3: Summary of Results of Mann-Kendall Trend Test and Stability Analysis

Monitoring Well	Monochlorobiphenyl		Dichlorobipenyl	
	Trend ≥ 90% Confidence Level	Stability	Trend ≥ 90% Confidence Level	Stability
PMA-MW-1M	No Trend	STABLE	n<4	n<4
PMA-MW-2M	No Trend	NA	n<4	n<4
PMA-MW-3M	DECREASING	NA	n<4	n<4
PMA-MW-3S	No Trend	NON-STABLE	n<4	n<4
PMA-MW-4D	No Trend	NA	No Trend	STABLE
PMA-MW-6D	No Trend	STABLE	n<4	n<4

Notes: **NA** - Stability could not be determined at the 80% confidence level because absolute value of the Mann-Kendall Statistic (S) was less than the number of events in the analysis.

n<4 indicates no data analyzed because all of the results were non-detects.

The Mann-Kendall Test evaluation of the data indicated the following for monochlorobiphenyl concentrations:

- In monitoring well PMA-MW-3M, these concentrations were decreasing at the 90% confidence level;
- In monitoring wells PMA-MW-1M and PMA-MW-6D, concentrations were stable;
- In monitoring wells PMA-MW-2M, PMA-MW-3M, and PMA-MW-4D, stability could not be determined at the 80% confidence level; and
- In monitoring well PMA-MW-3S, concentrations were non-stable.

Furthermore, the concentrations of dichlorobipenyl in PMA-MW-4D were stable during the monitoring period (i.e., during the past 8 quarters). Note that the concentrations of dichlorobipenyl in the other monitoring wells were below detection limits in all, or all but one, sampling rounds.

3.2.2 Mann-Whitney U Test

To further evaluate the analytical data, the Mann-Whitney U Test (also known as the Wilcoxon Rank-Sum Test) was conducted. This analysis is based on the ranks of the sample measurements rather than the actual concentrations (USEPA, 2009). Some statistical information contained in the original data is lost when using this test, since it only uses the relative magnitudes of data values. However, the benefit of the Mann-Whitney U Test is that the ranks can be used to conduct a statistical test even when the underlying population has an unusual form and is non-normal. Furthermore, the Mann-Whitney U Test can be adapted for use at small sites as an intrawell test, by comparing background concentrations to more recent measurements from the same well.

The USEPA (2009) notes that this test assumes that the tested populations are stationary over time, so that mean levels are not trending upward or downward. If trends are evident in time series plots of the sample data, the sample populations may need to be limited to only include data representative of relatively consistent groundwater conditions.

In these analyses, data from the first four quarters (Y1 Data) were considered to be one group that was compared to the data from the second four quarters (Y2 Data). For each well, the Wilcoxon statistic (W) was determined for Y1 Data and Y2 Data, and the W value was compared to the expected value of the Wilcoxon statistic, E(W). The data set that was greater than E(W) was considered to be the "compliance points" and the other data set was considered to be the "background point." This was done so the data evaluation would have non-negative values (i.e., values greater or equal to than 0).

The Mann-Whitney U Test needs to have a minimum of four data points in each of the sets being compared. Therefore, the data from monitoring well PMA-MW-4D could not be evaluated because it was not sampled during the first sampling round (3Q08) and the results from only seven analyses were available. The results of this analysis are summarized in **Table 4**, below, and supporting data and analyses are provided in **Attachment C**.

Table 4: Summary of Results of Mann-Whitney U Test

Monitoring Well	Monochlorobiphenyl	Dichlorobipenyl
	90% Confidence Level	90% Confidence Level
PMA-MW-1M	Stable	Not Analyzed, all non-detects
PMA-MW-2M	Stable/Slightly Decreasing	Not Analyzed, all non-detects
PMA-MW-3S	Stable	Stable
PMA-MW-3M	Stable	Not Analyzed, too few data
PMA-MW-4D	Not Analyzed, too few data	Not Analyzed, all non-detects
PMA-MW-6D	Stable	Not Analyzed, all non-detects

The results of the Mann-Whitney U Test for the monitoring wells with sufficient data to be evaluated indicated that the monochlorobiphenyl concentrations were generally stable. The dichlorobiphenyl concentrations in all of the monitoring wells except PMA-MW-3S were generally below detection limits. In monitoring well PMA-MW-3S this evaluation indicated that the dichlorobiphenyl concentrations were stable.

3.2.3 Pooled Variance Student's T-Test

The analytical data obtained during the monitoring period was also evaluated using the Pooled Variance Student's T-Test (the T-Test) to compare the Y1 Data to the Y2 Data, which were assumed to be two distinct statistical populations. This test was performed to determine whether the average concentration for the "compliance points" was the same as (or less than) the average concentration in "background points" (the null hypothesis), or whether the mean of the compliance points was larger than the mean of the background points. Specifically, the T-Test was used to determine that the more recently collected data (i.e., the Y2 Data) were consistent with the earlier data (i.e., the Y1 Data).

Specifically, if the results of the T-Test were non-significant, both data sets were considered part of the same statistical population. The Y1 Data and Y2 Data were identified as the compliance or background points based on the evaluation of the data performed for the Mann-Whitney U Test.

The T-Test evaluates the difference between the means of each sample population (USEPA, 2009). When this difference is small, a real difference between the means of the sample populations is considered unlikely. However, when the sample mean difference is large, a real difference between the populations seems likely, although an observed difference between the sample means does not automatically imply a true population difference.

Since the number of degrees of freedom also affects the shape of the sample distribution (i.e., the t-distribution), the magnitude of the critical points for a given confidence level selected from the t-distribution to provide a basis of comparison against the t-statistic. The USEPA (2009) notes that in a T-Test of whether compliance point concentrations exceed background point concentrations, a larger data set (i.e., more degrees of freedom) corresponds to a more robust test and greater confidence in the result (as represented by lower values for the t-statistic used in comparisons).

The T-Test assumes that the data set or group are statistically independent, and the data were assumed to meet this condition. The T-Test also assumes that the data are normally distributed. The distributions were evaluated by determining the following values: minimum, maximum, mean, median, first quartile, third quartile, standard deviation, and variance for the entire data set and for the Y1 and Y2 data sets, as shown in **Attachment B**. These values were plotted and reviewed to evaluate normal distributions by inspection, and all of the data sets appeared to be normally distributed. In addition, normal distributions were also confirmed prior to performing each test by using the Shapiro-Wilk Test, which is a formal numerical goodness-of-fit test of normality and considered to be a robust test of normality (USEPA, 2009). Based on the Shapiro-Wilk Test, the data sets for each well met the normal distribution criteria.

As with the Mann-Whitney U Test, the population means need to be stable or stationary over the time of data collection and testing, and the data sets were considered to meet this condition.

One final requirement for the T-Test is that each data set should have an adequate sample size (USEPA, 2009). The T-Test will only be able to identify the largest of concentration differences if the sample size in each data set is more than four, so four measurements in each set is generally considered a minimum requirement. However, the T-Test can be performed with as few as three points in each data set, which allowed the data sets from monitoring well PMA-MW-4D to be evaluated, which was not possible with the Mann-Whitney U Test.

The T-Tests were performed using the built-in function in Microsoft Excel for several different conditions (i.e., one or two tails, paired observations, unequal and equal variance), and the final evaluation was based on the conditions met by the data sets being compared. Based on the results of the T-Tests performed to compare the Y1 and Y2 Data Sets for each monitoring well, the sample populations met the null hypothesis. Therefore, the COI concentrations in each monitoring well were considered to be stable and not changing over time. Supporting data and analyses are provided in **Attachment C**.

3.2.4 Linear Regression

Linear regression was also used to evaluate the sample results for the COI at each monitoring well. These analyses were performed by plotting the data as a function of the number of days since the first sample was obtained to evaluate concentration changes over time. The built-in Microsoft Excel trend line function was then used to determine the equation of the linear trend line (i.e., in the form of $y = mx + b$) and the regression coefficient (R^2). The trend lines had very shallow positive and negative slopes (m in the range of -0.0006 to 0.0006), which indicates very slight changes in concentrations over time. Furthermore, the regression coefficients were in the range of 0.0017 to 0.3998. Since the regression coefficients were less than 0.60, this indicates that equations of the trend lines were not considered to be statistically significant. Also, review of the plots by visual inspection indicates that the data appear to be stable, which is consistent with the previous analyses. Supporting data and analyses are provided in **Attachment B**.

4.0 CONCLUSIONS

Our evaluation of the data from the groundwater monitoring conducted from 3Q08 through 2Q10 indicates the following:

1. The analytical results for samples collected during the monitoring period were as follows:

   a. PCBs were not detected in monitoring wells PMA-MW-1S, PMA-MW-2S, and PMA-MW-5M.

   b. Total PCB concentrations did not exceed 0.5 µg/L in monitoring wells PMA-MW-1M and PMA-MW-6D.

   c. Total PCB concentrations were slightly above the 0.5 µg/L level in monitoring wells PMA-MW-3M, PMA-MW-3S and PMA-MW-4D (e.g., 2Q10 results in the range of 0.63 to 0.82 µg/L).

   d. Total PCB concentrations in monitoring well PMA-MW-2M exceeded 0.5 µg/L (in the range of 2.4 to 4.1 µg/L).

   e. In the source area, DNAPL was present in monitoring well PMA-MW-4S during six, possibly seven, of the eight quarters.

2. The data exhibit seasonal behavior with regard to COI concentrations and groundwater elevation fluctuations, and six of the eight quarters (3Q08 and 2Q09 through 2Q10) were considered to be seasonally consistent. In particular, review of the combined plots of groundwater (potentiometric) elevations and COI concentrations versus time indicated that decreased groundwater elevations generally coincided with decreased COI concentrations. This was considered to be lower groundwater elevations interacting with a smaller volume of impacted soils and less PCB available to go into solution, which resulted in a decrease the monochlorobiphenyl and dichlorobiphenyl concentrations.

3. The results of the Mann-Kendall Test evaluation indicated the following:

   a. Monochlorobiphenyl concentrations in monitoring wells PMA-MW-1M and PMA-MW-6D were stable. In addition, this test indicated that the dichlorobiphenyl concentrations in PMA-MW-4D were stable;

   b. Trends in monochlorobiphenyl concentrations in the monitoring wells PMA-MW-2M and PMA-MW-4D could not be determined at the 80% confidence level because absolute value of the Mann-Kendall Statistic (S) was less than the number of events in the analysis;

   c. Monochlorobiphenyl concentrations in monitoring well PMA-MW-3M were decreasing at the 90% confidence level; and

   d. Monochlorobiphenyl concentrations in monitoring well PMA-MW-3S were non-stable at the 90% confidence level.

4. The Mann-Whitney U Test generally indicated that the analytical data from the 3rd quarter of 2008 through the 2nd quarter of 2009 and the data from the 3rd quarter of 2009 through the 2nd quarter of 2010 came from the same sample populations for each well, which indicates that the PCB concentrations were stable.

5. The Mann-Whitney U Test indicated that there may be a slight decreasing trend in PCB concentrations between the 3rd quarter of 2008 through the 2nd quarter of 2009 versus those from the 3rd quarter of 2009 through the 2nd quarter of 2010 at monitoring well PMA-MW-2M.

6. The Shapiro-Wilk Test indicated that the analytical data for each well was normally distributed.

7. The Pooled Variance Student's T-Test indicated that the analytical data from the first four quarters and the second four quarters appear to come from the same sample populations for each well, which indicates that the PCB concentrations were stable.

8. Linear regression analyses indicated that the analytical trend lines were slightly increasing to slightly decreasing with very little change over time. However, the regression coefficients indicated that equations for the trend lines were not statistically significant. Inspection of the plots of concentrations versus time indicated that the concentrations appear to be relatively stable.

Summarizing, the concentrations of the COI that were observed above the detection limits (specifically monochlorobiphenyl and dichlorobiphenyl) appeared to be generally stable and did not appear to increase or decrease over time.

5.0 RECOMMENDATIONS

Supported by data collected during this evaluation, listed below are recommendations for changes to the PCB Groundwater Quality Assessment Program:

1. Reduce sampling frequency to semi-annual, with sampling events occurring during the first and third quarters of each year, as groundwater levels during those quarters tend to be seasonally

consistent. This recommendation is consistent with US EPA's January 2007 "Technology Selection Report – Solutia Inc. W. G. Krummrich Facility, Sauget, Illinois."

2. Discontinue collecting samples at monitoring wells PMA-MW-1S, PMA-MW-2S, and PMA-MW-5M. PCB homologs have not been detected in these monitoring wells, and stable concentrations in the other wells indicate it is unlikely that these conditions will change.

REFERENCES

40 CFR Ch. I (7–1–02 Edition) Part 141, National Primary Drinking Water Regulations, from web site: http://www.access.gpo.gov/nara/cfr/waisidx_02/40cfr141_02.html.

Env. Tech. (1997) *1997 Resource Guide*, Environmental Technology, page 90.

Tingi et al. *2009* – University of Turin and University of Bologna, *Microbial Cell Factories 2009*, Vol 8, No 5, January 12, 2009

USEPA (2009) *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities – Unified Guidance*, EPA 530-R-09-007, U.S. Environmental Protection Agency, Office of Resource Conservation and Recovery, Program Implementation Division, March 2009

URS (2008) Sauget Area 2, Remedial Investigation Report, prepared by URS Corporation, October 2008.

URS (2008) 3rd Quarter 2008 Data Report, PCB Groundwater Quality Assessment Program, Solutia Inc. W.G. Krummrich Facility, prepared by URS Corporation, December 2008.

URS (2009) 4th Quarter 2008 Data Report, PCB Groundwater Quality Assessment Program, Solutia Inc. W.G. Krummrich Facility, prepared by URS Corporation, March 2009.

URS (2009) 1st Quarter 2009 Data Report, PCB Groundwater Quality Assessment Program, Solutia Inc. W.G. Krummrich Facility, prepared by URS Corporation, May 2009.

URS (2009) 2nd Quarter 2009 Data Report, PCB Groundwater Quality Assessment Program, Solutia Inc. W.G. Krummrich Facility, prepared by URS Corporation, August 2009.

URS (2009) 3rd Quarter 2009 Data Report, PCB Groundwater Quality Assessment Program, Solutia Inc. W.G. Krummrich Facility, prepared by URS Corporation, November 2009.

URS (2010) 4th Quarter 2009 Data Report, PCB Groundwater Quality Assessment Program, Solutia Inc. W.G. Krummrich Facility, prepared by URS Corporation, February 2010.

URS (2010) 1st Quarter 2010 Data Report, PCB Groundwater Quality Assessment Program, Solutia Inc. W.G. Krummrich Facility, prepared by URS Corporation, April 2010.

URS (2010) 2nd Quarter 2010 Data Report, PCB Groundwater Quality Assessment Program, Solutia Inc. W.G. Krummrich Facility, prepared by URS Corporation, July 2010.

ATTACHMENTS

FIGURES

ATTACHMENT A

Trend Evaluation of Monitoring Well Data 3Q08 through 2Q10

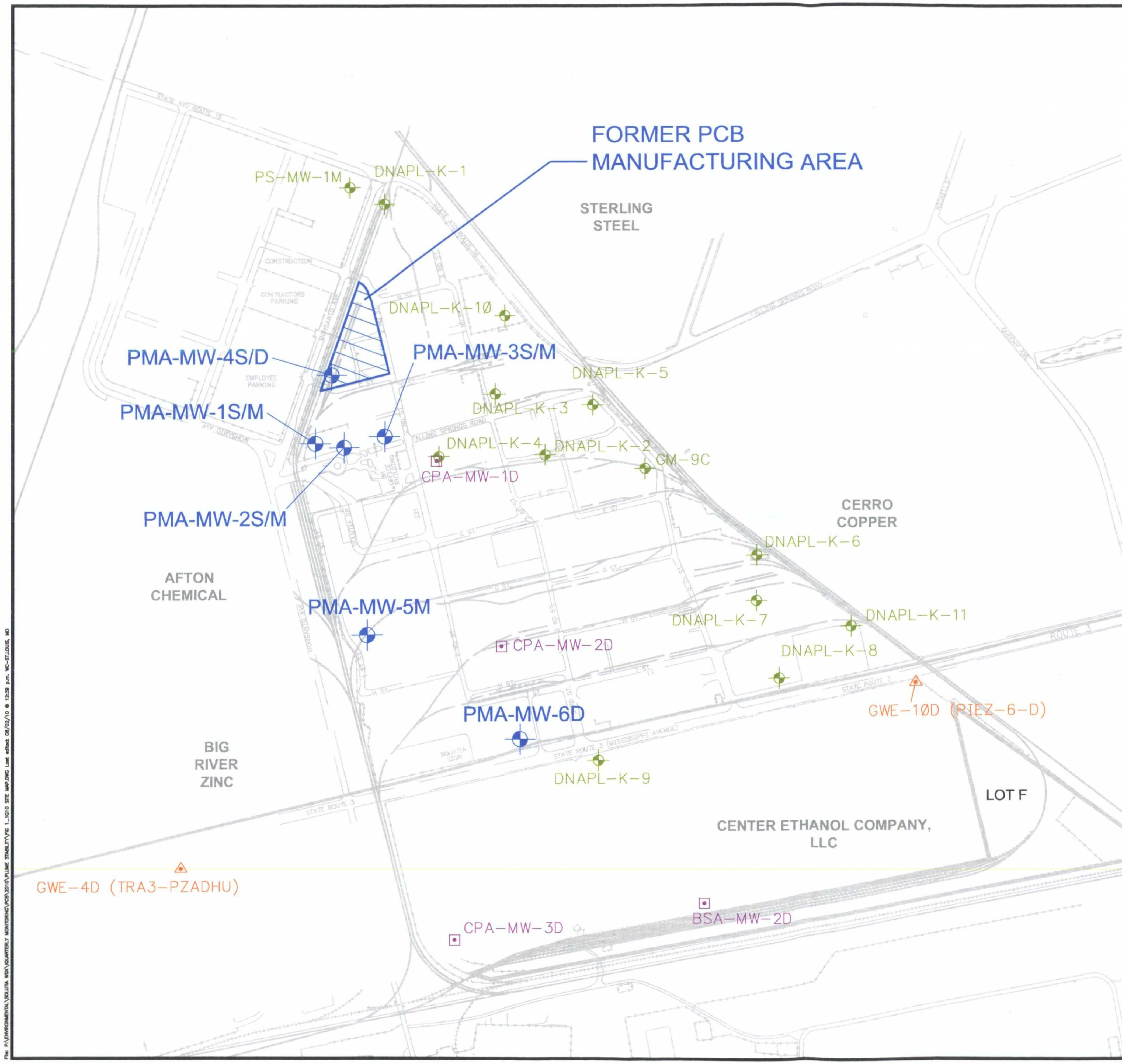
ATTACHMENT B

Mann-Kendall Analysis of Data 3Q08 through 2Q10

ATTACHMENT C

Mann-Whitney U Test Analysis of Data 3Q08 through 2Q10

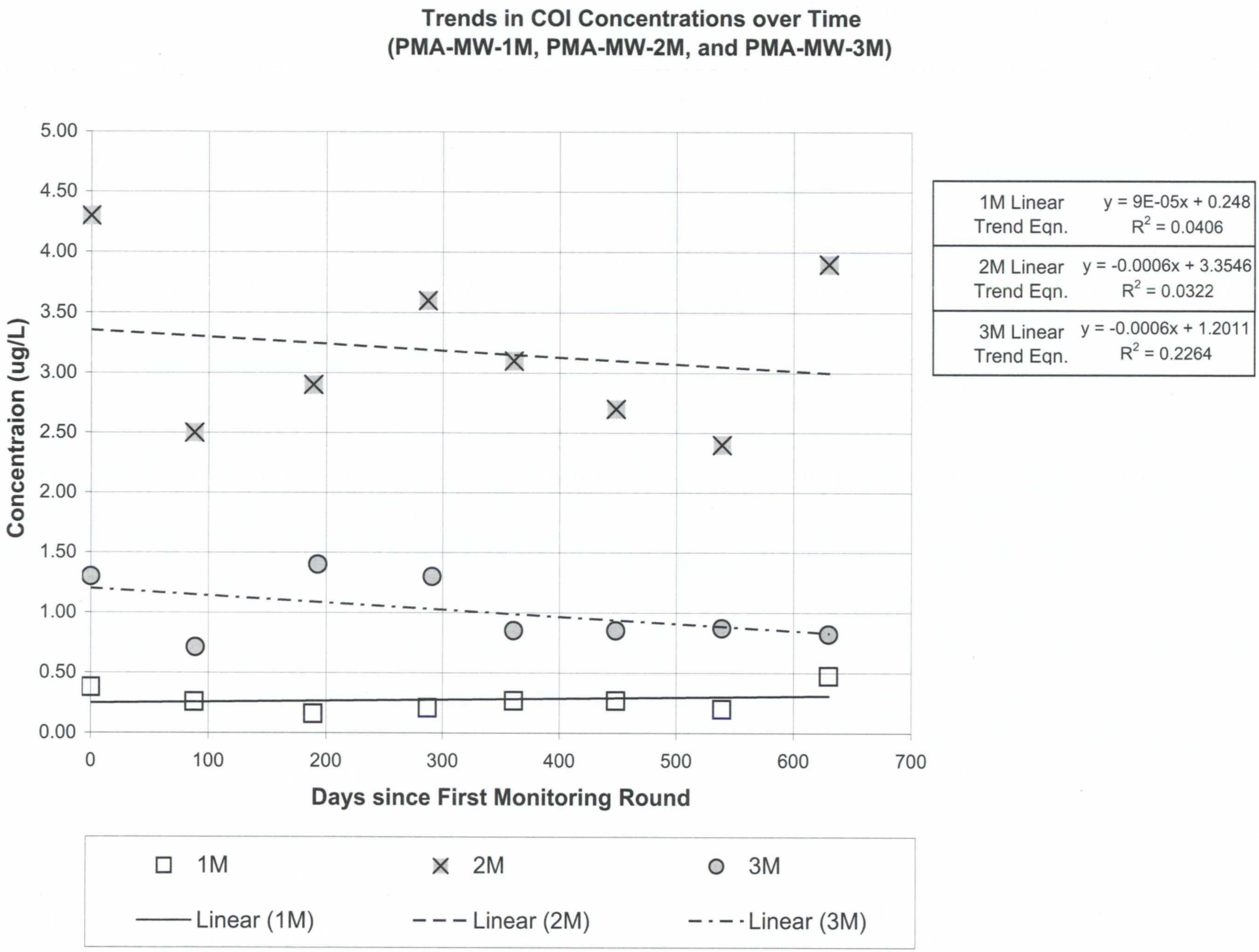
Figures



LEGEND

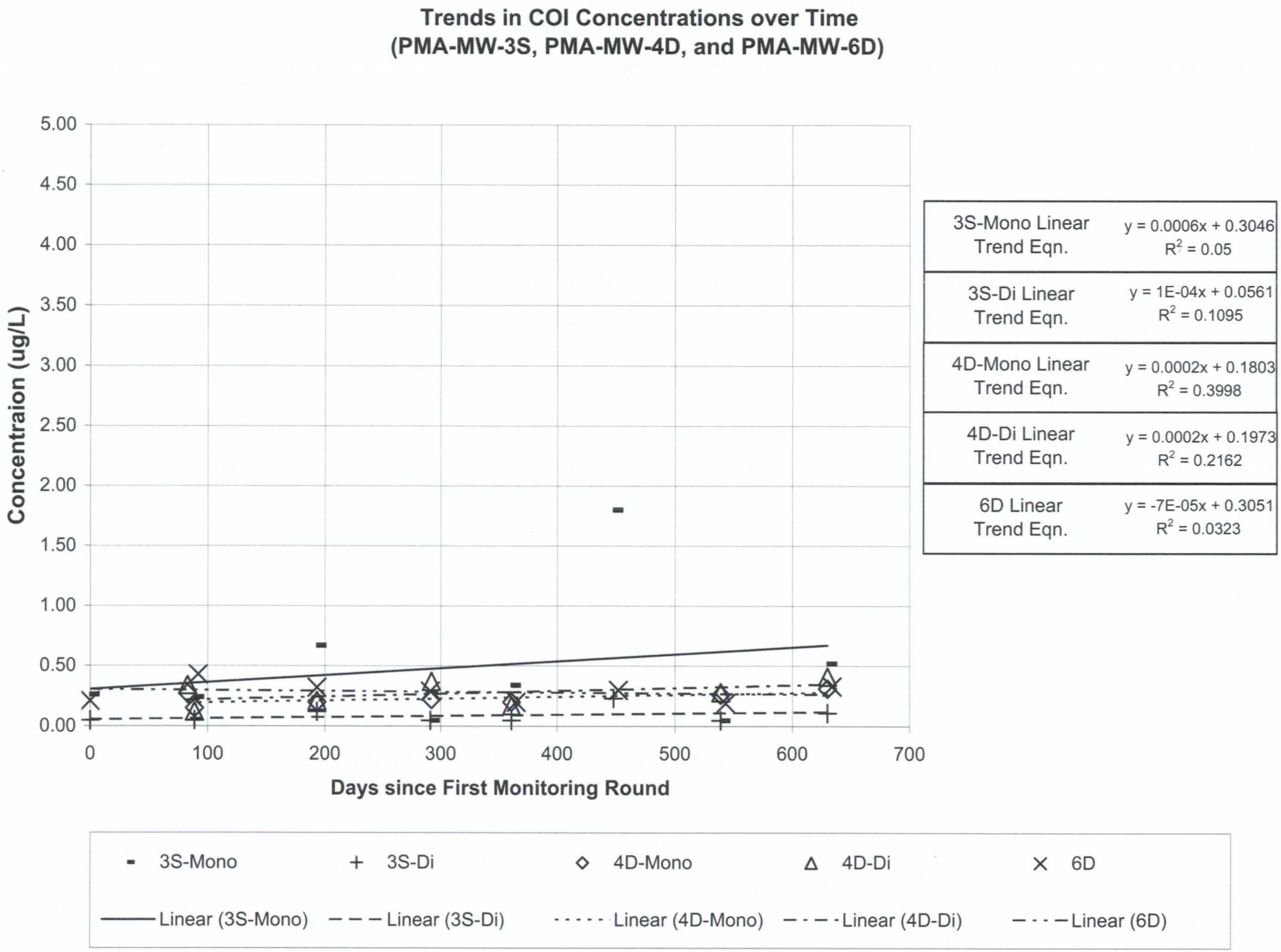
- PCB MONITORING WELL LOCATION
- LONG-TERM MONITORING WELL USED FOR GROUNDWATER CONTOURING
- OTHER MONITORING WELL USED FOR GROUNDWATER CONTOURING
- PIEZOMETER CLUSTER USED FOR GROUNDWATER CONTOURING

2010 EVALUATION W.G. KRUMMRICH FACILITY SAUGET, ILLINOIS		PROJECT NO. 21562401
URS		
DRN. BY:chs July 2010 DSGN. BY:djp CHKD. BY:	Site Map	FIG. NO. 1



W. G. Krummrich Facility
PCB Groundwater Quality Assessment Program
2010 Evaluation

FIGURE 2A



W. G. Krummrich Facility
PCB Groundwater Quality Assessment Program
2010 Evaluation

FIGURE 2B

Attachment A

ATTACHMENT A
PCB GW Quality Assessment Analytical Detections

Well ID	Units	Chemical Group	Chemical	3rd Quarter 2008 Result	4th Quarter 2008 Result	1st Quarter 2009 Result	2nd Quarter 2009 Result
				Results in Red are non-detects, half of detection limit			
Date				8/22/2008	11/18/2008	2/27/2009	6/5/2009
Water Level		elev (ft)		400.15	396.53	395.5	401.27
1M	ug/L	PCBs	Monochlorobiphenyl	0.38	0.26	0.16	0.21
Date				8/22/2008	11/18/2008	2/27/2009	6/5/2009
Water Level		elev (ft)		400.27	396.88	395.57	401.32
2M	ug/L	PCBs	Dichlorobiphenyl	0.0485	0.0485	0.05	0.54
2M	ug/L	PCBs	Monochlorobiphenyl	4.3	2.5	2.9	3.6
2M-DUP	ug/L	PCBs	Monochlorobiphenyl	4	2.7	2	3.2
Date				8/22/2008	11/19/2008	3/3/2009	6/9/2009
Water Level		elev (ft)		400.46	397.35	395.7	401.2
3M	ug/L	PCBs	Monochlorobiphenyl	1.3	0.71	1.4	1.3
Date				8/22/2008	11/19/2008	3/3/2009	6/9/2009
Water Level		elev (ft)		400.53	397.39	395.68	401.08
3S	ug/L	PCBs	Dichlorobiphenyl	0.0485	0.05	0.12	0.047
3S	ug/L	PCBs	Monochlorobiphenyl	0.26	0.24	0.67	0.047
Date				8/22/2008	11/19/2008	3/3/2009	6/10/2009
Water Level		elev (ft)		MN	397.45	395.98	401.25
4D	ug/L	PCBs	Dichlorobiphenyl	NA	0.12	0.21	0.37
4D	ug/L	PCBs	Heptachlorobiphenyl	NA	0.145	0.5	0.14
4D	ug/L	PCBs	Hexachlorobiphenyl	NA	0.095	0.79	0.095
4D	ug/L	PCBs	Monochlorobiphenyl	NA	0.15	0.2	0.22
4D	ug/L	PCBs	Pentachlorobiphenyl	NA	0.095	0.38	0.095
4D	ug/L	PCBs	Tetrachlorobiphenyl	NA	0.095	0.54	0.095
4D	ug/L	PCBs	Trichlorobiphenyl	NA	0.0485	0.11	0.047

ATTACHMENT A
PCB GW Quality Assessment Analytical Detections

Well ID	Units	Chemical Group	Chemical	3rd Quarter 2008 Result	4th Quarter 2008 Result	1st Quarter 2009 Result	2nd Quarter 2009 Result
				Results in Red are non-detects, half of detection limit			
Date				8/22/2008	11/19/2008	3/3/2009	6/10/2009
Water Level		elev (ft)		NM	NM	395.1	NM
4S	ug/L	PCBs	Decachlorobiphenyl	NA	NA	NA	NA
4S	ug/L	PCBs	Dichlorobiphenyl	NA	NA	NA	NA
4S	ug/L	PCBs	Heptachlorobiphenyl	NA	NA	NA	NA
4S	ug/L	PCBs	Hexachlorobiphenyl	NA	NA	NA	NA
4S	ug/L	PCBs	Monochlorobiphenyl	NA	NA	NA	NA
4S	ug/L	PCBs	Nonachlorobiphenyl	NA	NA	NA	NA
4S	ug/L	PCBs	Octachlorobiphenyl	NA	NA	NA	NA
4S	ug/L	PCBs	Pentachlorobiphenyl	NA	NA	NA	NA
4S	ug/L	PCBs	Tetrachlorobiphenyl	NA	NA	NA	NA
4S	ug/L	PCBs	Trichlorobiphenyl	NA	NA	NA	NA
Date				8/18/2008	11/18/2008	2/27/2009	6/5/2009
Water Level		elev (ft)		401.20	396.46	394.82	402.78
6D	ug/L	PCBs	Monochlorobiphenyl	0.21	0.43	0.32	0.29
6D-F	ug/L	PCBs	Monochlorobiphenyl	0.12			

ATTACHMENT A
PCB GW Quality Assessment Analytical Detections

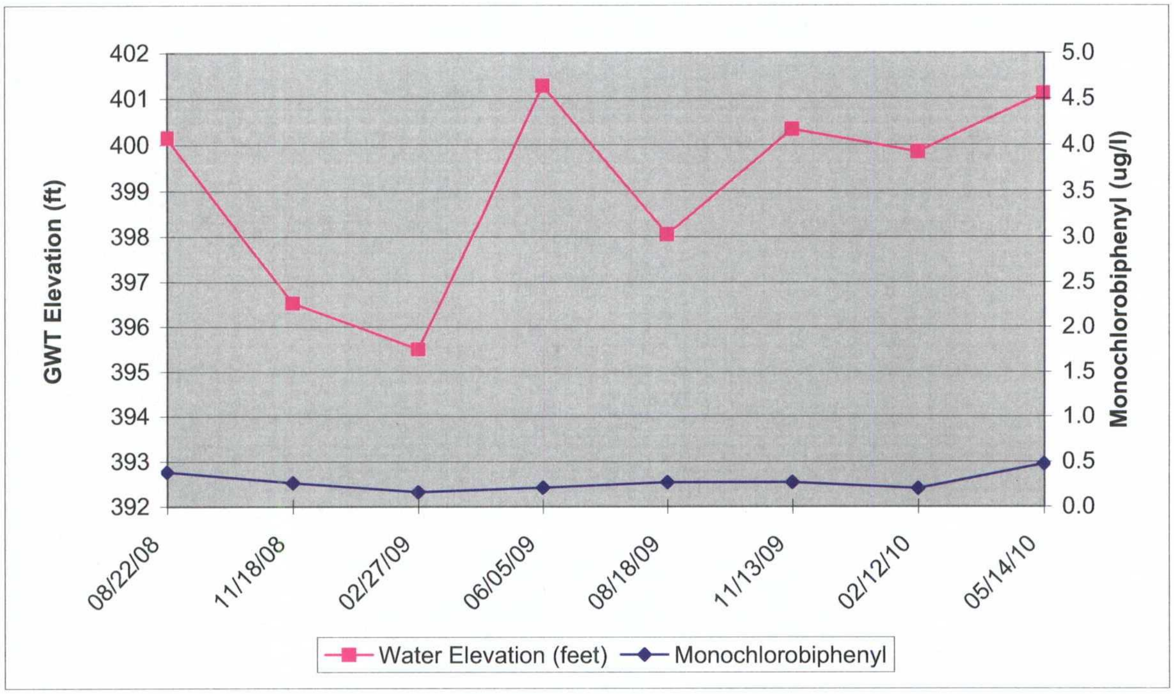
Well ID	Units	Chemical Group	Chemical	3rd Quarter 2009 Result	4th Quarter 2009 Result	1st Quarter 2010 Result	2nd Quarter 2010 Result
				Results in Red are non-detects, half of detection limit			
Date				8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		elev (ft)		398.05	400.33	399.85	401.11
1M	ug/L	PCBs	Monochlorobiphenyl	0.27	0.27	0.2	0.475
Date				8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		elev (ft)		398.16	400.33	399.87	401.25
2M	ug/L	PCBs	Dichlorobiphenyl	0.047	0.0475	0.047	0.495
2M	ug/L	PCBs	Monochlorobiphenyl	3.1	2.7	2.4	3.9
2M-DUP	ug/L	PCBs	Monochlorobiphenyl	1.8	3.4	2.4	4
Date				8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		elev (ft)		398.32	400.39	400.02	401.21
3M	ug/L	PCBs	Monochlorobiphenyl	0.85	0.85	0.87	0.82
Date				8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		elev (ft)		398.39	400.35	400.04	401.22
3S	ug/L	PCBs	Dichlorobiphenyl	0.047	0.23	0.0475	0.11
3S	ug/L	PCBs	Monochlorobiphenyl	0.34	1.8	0.0475	0.52
Date				8/18/2009	11/13/2008	2/12/2010	5/14/2010
Water Level		elev (ft)		398.34	400.66	400.17	401.27
4D	ug/L	PCBs	Dichlorobiphenyl	0.17	0.34	0.28	0.41
4D	ug/L	PCBs	Heptachlorobiphenyl	0.14	0.145	0.14	0.145
4D	ug/L	PCBs	Hexachlorobiphenyl	0.095	0.095	0.095	0.095
4D	ug/L	PCBs	Monochlorobiphenyl	0.2	0.27	0.26	0.31
4D	ug/L	PCBs	Pentachlorobiphenyl	0.095	0.095	0.095	0.095
4D	ug/L	PCBs	Tetrachlorobiphenyl	0.095	0.095	0.095	0.095
4D	ug/L	PCBs	Trichlorobiphenyl	0.047	0.0475	0.047	0.0485

ATTACHMENT A
PCB GW Quality Assessment Analytical Detections

Well ID	Units	Chemical Group	Chemical	3rd Quarter 2009 Result	4th Quarter 2009 Result	1st Quarter 2010 Result	2nd Quarter 2010 Result
				Results in Red are non-detects, half of detection limit			
Date				8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		elev (ft)		398.76	400.09	400.08	401.35
4S	ug/L	PCBs	Decachlorobiphenyl	NA	NA	0.85	24.5
4S	ug/L	PCBs	Dichlorobiphenyl	NA	NA	6.8	43
4S	ug/L	PCBs	Heptachlorobiphenyl	NA	NA	33	470
4S	ug/L	PCBs	Hexachlorobiphenyl	NA	NA	49	620
4S	ug/L	PCBs	Monochlorobiphenyl	NA	NA	1.4	4.85
4S	ug/L	PCBs	Nonachlorobiphenyl	NA	NA	1.2	24.5
4S	ug/L	PCBs	Octachlorobiphenyl	NA	NA	8.3	78
4S	ug/L	PCBs	Pentachlorobiphenyl	NA	NA	34	370
4S	ug/L	PCBs	Tetrachlorobiphenyl	NA	NA	52	410
4S	ug/L	PCBs	Trichlorobiphenyl	NA	NA	14	140
Date				8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		elev (ft)		397.43	401.11	399.54	402.35
6D	ug/L	PCBs	Monochlorobiphenyl	0.2	0.3	0.19	0.33
6D-F	ug/L	PCBs	Monochlorobiphenyl				

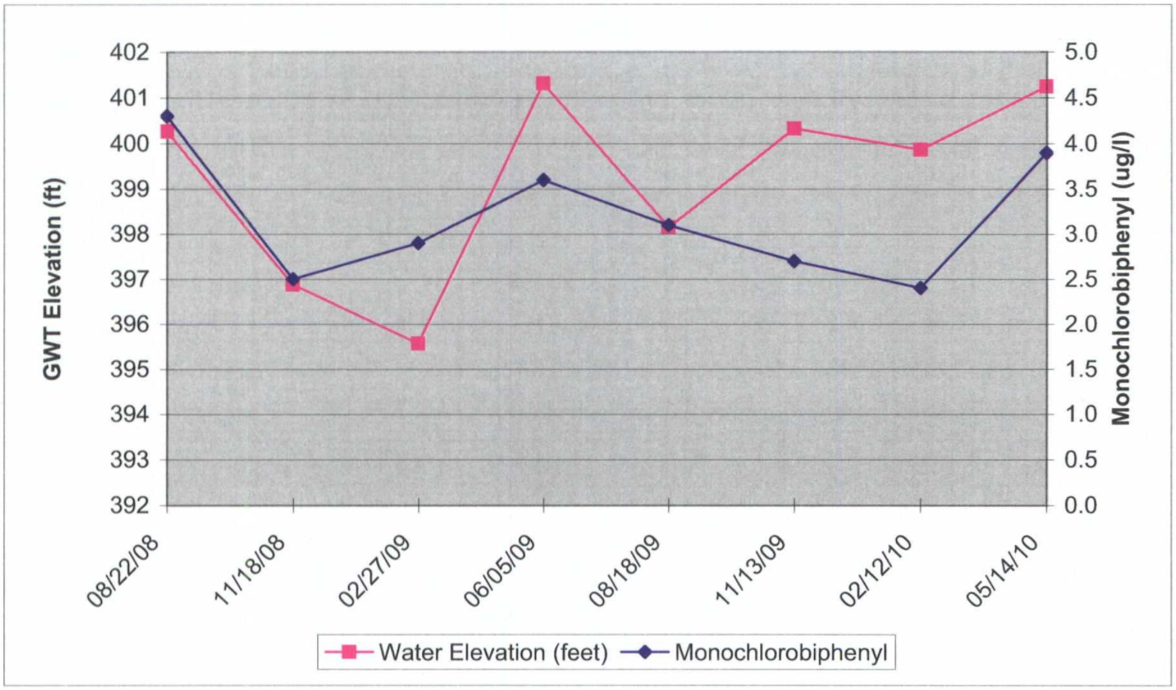
ATTACHMENT A

Supporting Data for PCB Groundwater Evalaution 3Q08 through 2Q10
Comparison of COI to Groundwater Levels over Time
Monitoring Well PMA-MW-1M



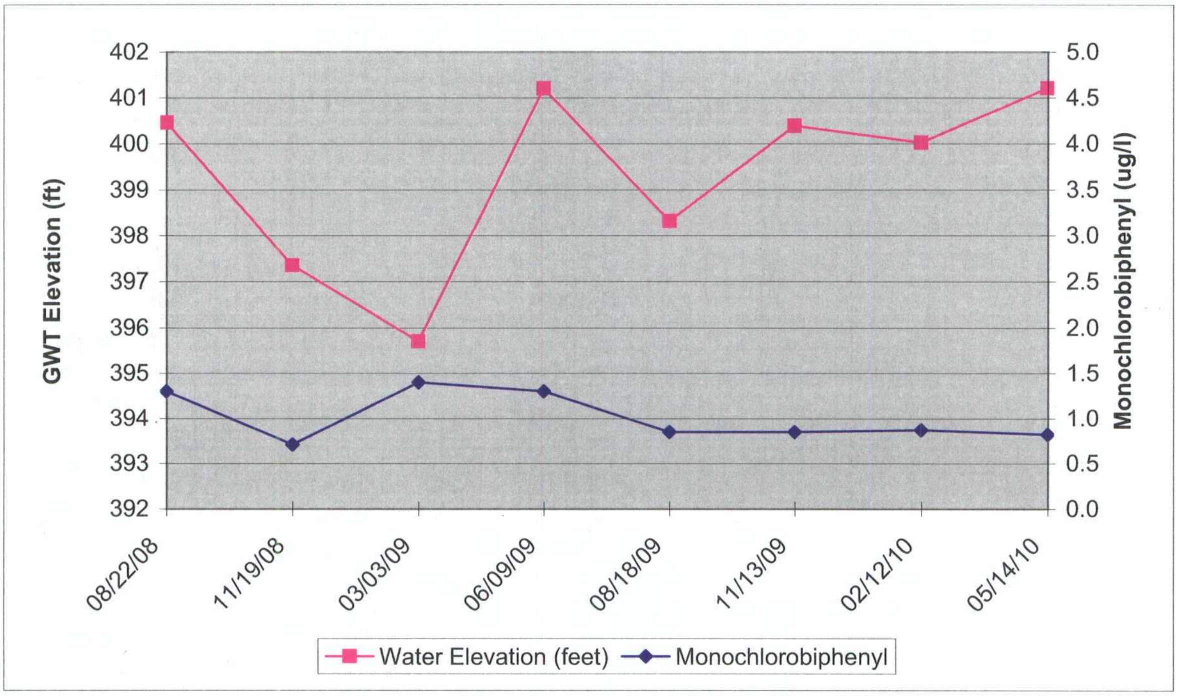
ATTACHMENT A

Supporting Data for PCB Groundwater Evalaution 3Q08 through 2Q10
Comparison of COI to Groundwater Levels over Time
Monitoring Well PMA-MW-2M

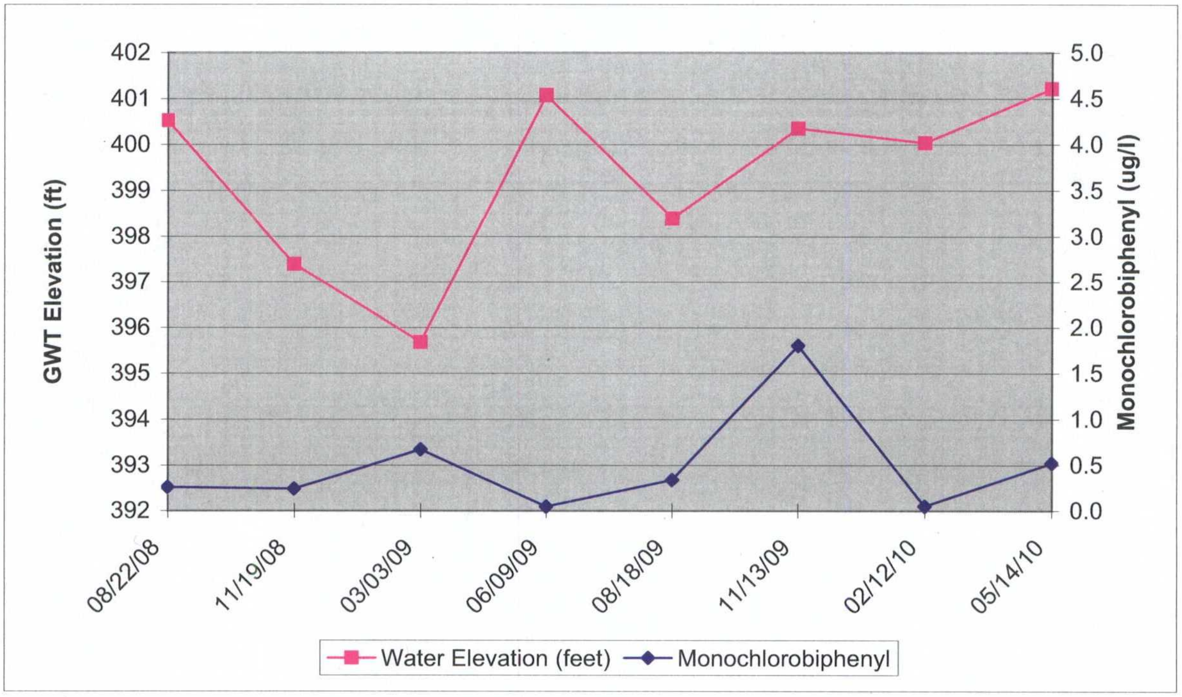


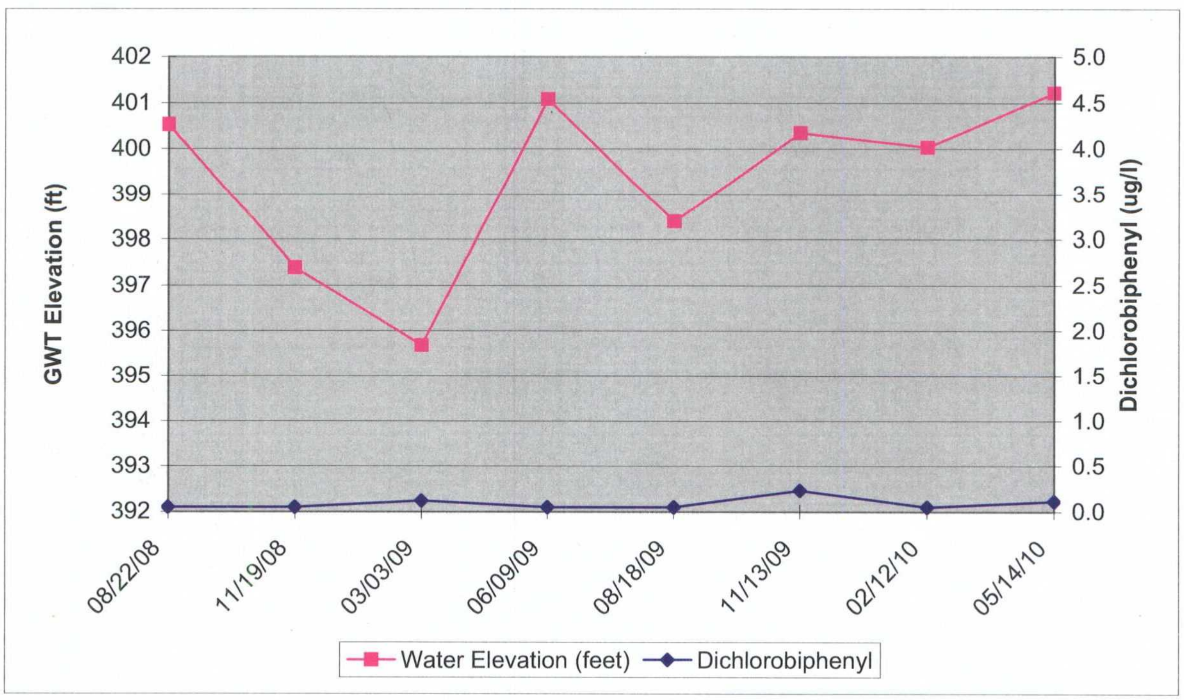
ATTACHMENT A

Supporting Data for PCB Groundwater Evalaution 3Q08 through 2Q10
Comparison of COI to Groundwater Levels over Time
Monitoring Well PMA-MW-3M



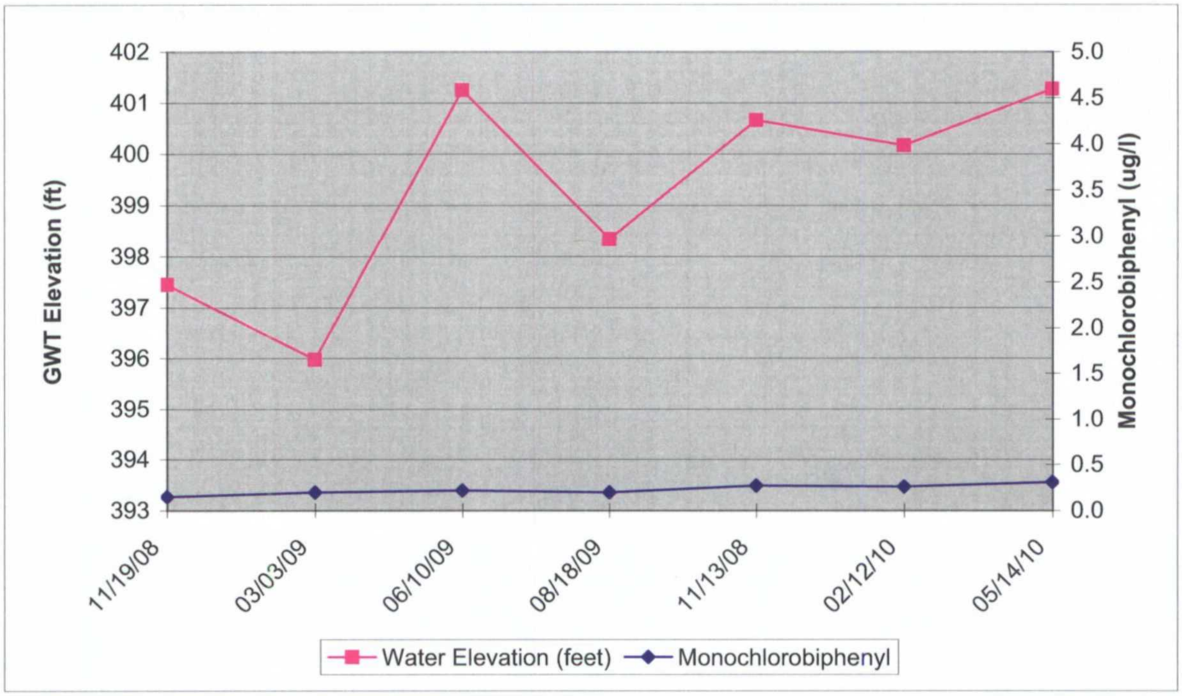
ATTACHMENT A
Supporting Data for PCB Groundwater Evalaution 3Q08 through 2Q10
Comparison of COI to Groundwater Levels over Time
Monitoring Well PMA-MW-3S

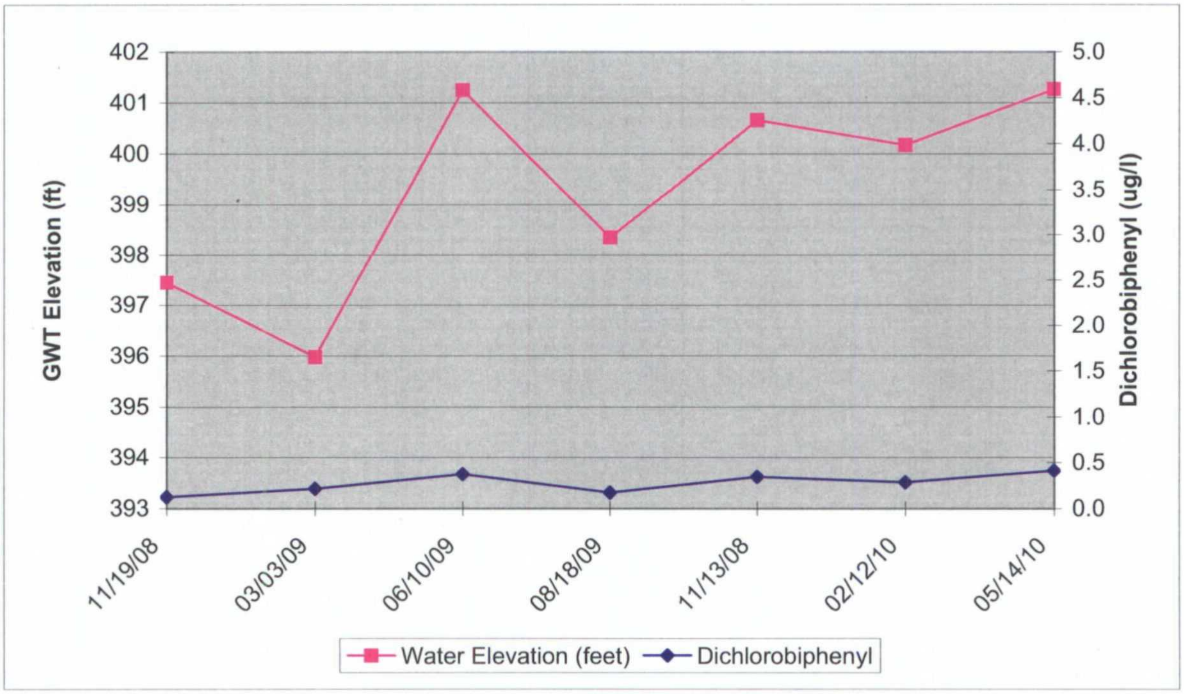




ATTACHMENT A

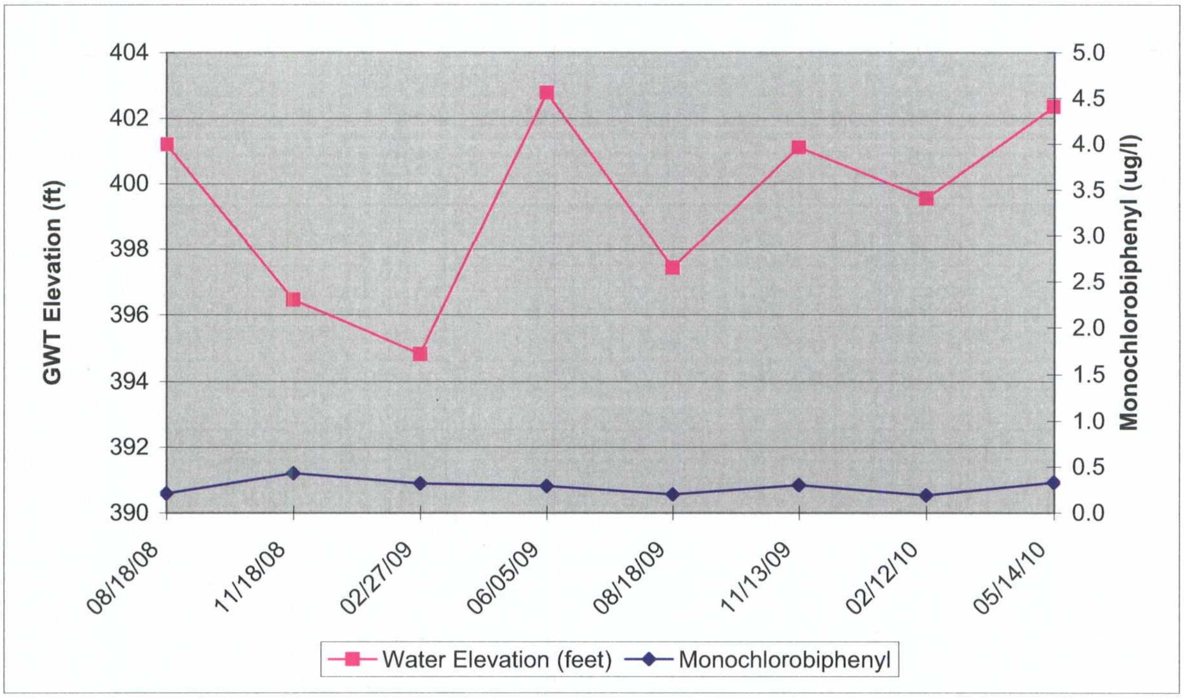
Supporting Data for PCB Groundwater Evalaution 3Q08 through 2Q10
Comparison of COI to Groundwater Levels over Time
Monitoring Well PMA-MW-4D





ATTACHMENT A

Supporting Data for PCB Groundwater Evalaution 3Q08 through 2Q10
Comparison of COI to Groundwater Levels over Time
Monitoring Well PMA-MW-6D



Attachment B

ATTACHMENT B

Mann-Kendall Analysis of PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-1M

State of Wisconsin | **Mann-Kendall Statistical Test**
Department of Natural Resources | **Form 4400-215 (2/2001)**
Remediation and Redevelopment Program | **Revised to Evaluate Trend at ≥ 95% Confidence Level**

Notice: This form is the DNR supplied spreadsheet referenced in Appendices A of Comm 46 and NR 746, Wis. Adm. Code. It is provided to consultants as an optional tool for groundwater contaminant trend analysis to support site closure requests under s. Comm 46.07, Comm 46.08, NR 746.07, NR 746.08, Wis. Adm. Code. Use this form or a manual method when seeking case closure under those rules. Earlier versions of this form should not be used.

Instructions: Do not change formulas or other information in cells with a blue background, only cells with a yellow background are used for data entry. To use the spreadsheet, provide at least four rounds and not more than ten rounds of data that is not seasonally affected. Use consistent units. The spreadsheet contains several error checks, and a data entry error may cause "DATA ERR" or "DATE ERR" to be displayed. Dates that are not consecutive will show an error message and will not display the test results. The spreadsheet tests the data for both increasing and decreasing trends at both 80 percent and 90 percent confidence levels. If a declining trend is present at 80 percent but not at 90 percent, a site is still eligible for closure under Comm 46 and NR 746 provided that other conditions in those rules are met. If an increasing or decreasing trend is not present, an additional coefficient of variation test is used to test for stability, as proposed by Wiedemeier et al, 1999. For additional information, refer to the Interim Guidance on Natural Attenuation for Petroleum Releases, dated October 1999. Refer to the guidance for recommendations on data entry for non-detect values.

Site Name = Solutia WGK Site | BRRTS No. = | Well Number = 1M

Event Number	Compound -> / Sampling Date (most recent last)	Monochlorobiphenyl Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)
1	22-Aug-08	0.38					
2	5-Jun-09	0.21					
3	18-Aug-09	0.27					
4	13-Nov-09	0.27					
5	12-Feb-10	0.20					
6	14-May-10	0.48					
7							
8							
9							
10							
	Mann Kendall Statistic (S) =	0.0	0.0	0.0	0.0	0.0	0.0
	Number of Rounds (n) =	6	0	0	0	0	0
	Average =	0.30	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Standard Deviation =	0.107	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Coefficient of Variation(CV)=	0.355	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Error Check, Blank if No Errors Detected			n<4	n<4	n<4	n<4	n<4
Trend ≥ 80% Confidence Level		No Trend	n<4	n<4	n<4	n<4	n<4
Trend ≥ 90% Confidence Level		No Trend	n<4	n<4	n<4	n<4	n<4
Trend ≥ 95% Confidence Level		No Trend	n<4	n<4	n<4	n<4	n<4
Stability Test, If No Trend Exists at 80% Confidence Level		CV <= 1 STABLE	n<4 n<4	n<4 n<4	n<4 n<4	n<4 n<4	n<4 n<4

Data Entry By = PWS | Date = 22-Jun-10 | Checked By = WAN

ATTACHMENT B
Mann-Kendall Analysis of PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-2M

State of Wisconsin
Department of Natural Resources
Remediation and Redevelopment Program

Mann-Kendall Statistical Test
Form 4400-215 (2/2001)
Revised to Evaluate Trend at ≥ 95% Confidence Level

Notice: This form is the DNR supplied spreadsheet referenced in Appendices A of Comm 46 and NR 746, Wis. Adm. Code. It is provided to consultants as an optional tool for groundwater contaminant trend analysis to support site closure requests under s. Comm 46.07, Comm 46.08, NR 746.07, NR 746.08, Wis. Adm. Code. Use this form or a manual method when seeking case closure under those rules. Earlier versions of this form should not be used.

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Site Name = Solutia WGK Site			BRRTS No. =		Well Number =	2M	
	Compound ->	Monochlorobiphenyl					
Event Number	Sampling Date (most recent last)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)
1	22-Aug-08	4.3					
2	5-Jun-09	3.6					
3	18-Aug-09	3.1					
4	13-Nov-09	2.7					
5	12-Feb-10	2.4					
6	14-May-10	3.9					
7							
8							
9							
10							
	Mann Kendall Statistic (S) =	-7.0	0.0	0.0	0.0	0.0	0.0
	Number of Rounds (n) =	6	0	0	0	0	0
	Average =	3.33	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Standard Deviation =	0.728	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Coefficient of Variation(CV)=	0.219	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Error Check, Blank if No Errors Detected			n<4	n<4	n<4	n<4	n<4
Trend ≥ 80% Confidence Level		**DECREASING**	n<4	n<4	n<4	n<4	n<4
Trend ≥ 90% Confidence Level		No Trend	n<4	n<4	n<4	n<4	n<4
Trend ≥ 95% Confidence Level		No Trend	n<4	n<4	n<4	n<4	n<4
Stability Test, If No Trend Exists at 80% Confidence Level		NA	n<4 n<4	n<4 n<4	n<4 n<4	n<4 n<4	n<4 n<4
	Data Entry By = PWS		Date = 22-Jun-10		Checked By = WAN		

ATTACHMENT B

Mann-Kendall Analysis of PCB Data 3Q08 through 2Q10

Monitoring Well PMA-MW-3M

State of Wisconsin
Department of Natural Resources
Remediation and Redevelopment Program

Mann-Kendall Statistical Test
Form 4400-215 (2/2001)
Revised to Evaluate Trend at ≥ 95% Confidence Level

Notice: This form is the DNR supplied spreadsheet referenced in Appendices A of Comm 46 and NR 746, Wis. Adm. Code. It is provided to consultants as an optional tool for groundwater contaminant trend analysis to support site closure requests under s. Comm 46.07, Comm 46.08, NR 746.07, NR 746.08, Wis. Adm. Code. Use this form or a manual method when seeking case closure under those rules. Earlier versions of this form should not be used.

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Site Name = Solutia WGK Site | BRRTS No. = | Well Number = 3M

Event Number	Sampling Date (most recent last)	Compound -> Monochlorobiphenyl Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)
1	22-Aug-08	1.3					
2	9-Jun-09	1.30					
3	18-Aug-09	0.9					
4	13-Nov-09	0.9					
5	12-Feb-10	0.87					
6	14-May-10	0.82					
7							
8							
9							
10							
	Mann Kendall Statistic (S) =	-9.0	0.0	0.0	0.0	0.0	0.0
	Number of Rounds (n) =	6	0	0	0	0	0
	Average =	1.00	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Standard Deviation =	0.234	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Coefficient of Variation(CV)=	0.235	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Error Check, Blank if No Errors Detected			n<4	n<4	n<4	n<4	n<4
Trend ≥ 80% Confidence Level		DECREASING	n<4	n<4	n<4	n<4	n<4
Trend ≥ 90% Confidence Level		DECREASING	n<4	n<4	n<4	n<4	n<4
Trend ≥ 95% Confidence Level		No Trend	n<4	n<4	n<4	n<4	n<4
Stability Test, If No Trend Exists at 80% Confidence Level		NA	n<4 n<4	n<4 n<4	n<4 n<4	n<4 n<4	n<4 n<4

Data Entry By = PWS | Date = 22-Jun-10 | Checked By = WAN

ATTACHMENT B

Mann-Kendall Analysis of PCB Data 3Q08 through 2Q10

Monitoring Well PMA-MW-3S

State of Wisconsin
Department of Natural Resources
Remediation and Redevelopment Program

Mann-Kendall Statistical Test
Form 4400-215 (2/2001)
Revised to Evaluate Trend at ≥ 95% Confidence Level

Notice: This form is the DNR supplied spreadsheet referenced in Appendices A of Comm 46 and NR 746, Wis. Adm. Code. It is provided to consultants as an optional tool for groundwater contaminant trend analysis to support site closure requests under s. Comm 46.07, Comm 46.08, NR 746.07, NR 746.08, Wis. Adm. Code. Use this form or a manual method when seeking case closure under those rules. Earlier versions of this form should not be used.

Instructions: Do not change formulas or other information in cells with a blue background, only cells with a yellow background are used for data entry. To use the spreadsheet, provide at least four rounds and not more than ten rounds of data that is not seasonally affected. Use consistent units. The spreadsheet contains several error checks, and a data entry error may cause "DATA ERR" or "DATE ERR" to be displayed. Dates that are not consecutive will show an error message and will not display the test results. The spreadsheet tests the data for both increasing and decreasing trends at both 80 percent and 90 percent confidence levels. If a declining trend is present at 80 percent but not at 90 percent, a site is still eligible for closure under Comm 46 and NR 746 provided that other conditions in those rules are met. If an increasing or decreasing trend is not present, an additional coefficient of variation test is used to test for stability, as proposed by Wiedemeier et al, 1999. For additional information, refer to the Interim Guidance on Natural Attenuation for Petroleum Releases, dated October 1999. Refer to the guidance for recommendations on data entry for non-detect values.

Site Name = Solutia WGK Site | BRRTS No. = | Well Number = 3S

Event Number	Sampling Date (most recent last)	Monochlorobiphenyl Concentration (blank if no data; Red if ND/2 used)	Dichlorobiphenyl Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)
1	22-Aug-08	0.26					
2	9-Jun-09	0.047					
3	18-Aug-09	0.34					
4	13-Nov-09	1.8	0.23				
5	12-Feb-10	0					
6	14-May-10	0.52	0.11				
7							
8							
9							
10							
	Mann Kendall Statistic (S) =	5.0	-1.0	0.0	0.0	0.0	0.0
	Number of Rounds (n) =	6	2	0	0	0	0
	Average =	0.50	0.17	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Standard Deviation =	0.661	0.085	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Coefficient of Variation(CV)=	1.315	0.499	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Error Check, Blank if No Errors Detected			n<4	n<4	n<4	n<4	n<4
Trend ≥ 80% Confidence Level		No Trend	n<4	n<4	n<4	n<4	n<4
Trend ≥ 90% Confidence Level		No Trend	n<4	n<4	n<4	n<4	n<4
Trend ≥ 95% Confidence Level		No Trend	n<4	n<4	n<4	n<4	n<4
Stability Test, If No Trend Exists at 80% Confidence Level		CV > 1 NON-STABLE	n<4 n<4	n<4 n<4	n<4 n<4	n<4 n<4	n<4 n<4

Data Entry By = PWS | Date = 22-Jun-10 | Checked By = WAN

ATTACHMENT B

Mann-Kendall Analysis of PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-4D

State of Wisconsin
Department of Natural Resources
Remediation and Redevelopment Program

Mann-Kendall Statistical Test
Form 4400-215 (2/2001)
Revised to Evaluate Trend at ≥ 95% Confidence Level

Notice: This form is the DNR supplied spreadsheet referenced in Appendices A of Comm 46 and NR 746, Wis. Adm. Code. It is provided to consultants as an optional tool for groundwater contaminant trend analysis to support site closure requests under s. Comm 46.07, Comm 46.08, NR 746.07, NR 746.08, Wis. Adm. Code. Use this form or a manual method when seeking case closure under those rules. Earlier versions of this form should not be used.

Instructions: Do not change formulas or other information in cells with a blue background, only cells with a yellow background are used for data entry. To use the spreadsheet, provide at least four rounds and not more than ten rounds of data that is not seasonally affected. Use consistent units. The spreadsheet contains several error checks, and a data entry error may cause "DATA ERR" or "DATE ERR" to be displayed. Dates that are not consecutive will show an error message and will not display the test results. The spreadsheet tests the data for both increasing and decreasing trends at both 80 percent and 90 percent confidence levels. If a declining trend is present at 80 percent but not at 90 percent, a site is still eligible for closure under Comm 46 and NR 746 provided that other conditions in those rules are met. If an increasing or decreasing trend is not present, an additional coefficient of variation test is used to test for stability, as proposed by Wiedemeier et al, 1999. For additional information, refer to the Interim Guidance on Natural Attenuation for Petroleum Releases, dated October 1999. Refer to the guidance for recommendations on data entry for non-detect values.

Site Name = Solutia WGK Site | BRRTS No. = | Well Number = 4D

Event Number	Compound -> / Sampling Date (most recent last)	Monochlorobiphenyl Concentration (blank if no data; Red if ND/2 used)	Dichlorobiphenyl Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)
1	10-Jun-09	0.22	0.37				
2	18-Aug-09	0.2	0.17				
3	13-Nov-09	0.27	0.34				
4	12-Feb-10	0.26	0.28				
5	14-May-10	0.31	0.41				
6							
7							
8							
9							
10							
	Mann Kendall Statistic (S) =	6.0	2.0	0.0	0.0	0.0	0.0
	Number of Rounds (n) =	5	5	0	0	0	0
	Average =	0.25	0.31	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Standard Deviation =	0.043	0.093	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Coefficient of Variation(CV)=	0.172	0.298	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Error Check, Blank if No Errors Detected				n<4	n<4	n<4	n<4
Trend ≥ 80% Confidence Level		INCREASING	No Trend	n<4	n<4	n<4	n<4
Trend ≥ 90% Confidence Level		No Trend	No Trend	n<4	n<4	n<4	n<4
Trend ≥ 95% Confidence Level		No Trend	No Trend	n<4	n<4	n<4	n<4
Stability Test, If No Trend Exists at 80% Confidence Level		NA	CV <= 1 STABLE	n<4 n<4	n<4 n<4	n<4 n<4	n<4 n<4

Data Entry By = PWS | Date = 22-Jun-10 | Checked By = WAN

State of Wisconsin
Department of Natural Resources
Remediation and Redevelopment Program

Mann-Kendall Statistical Test
Form 4400-215 (2/2001)
Revised to Evaluate Trend at ≥ 95% Confidence Level

Notice: This form is the DNR supplied spreadsheet referenced in Appendices A of Comm 46 and NR 746, Wis. Adm. Code. It is provided to consultants as an optional tool for groundwater contaminant trend analysis to support site closure requests under s. Comm 46.07, Comm 46.08, NR 746.07, NR 746.08, Wis. Adm. Code. Use this form or a manual method when seeking case closure under those rules. Earlier versions of this form should not be used.

Instructions: Do not change formulas or other information in cells with a blue background, only cells with a yellow background are used for data entry. To use the spreadsheet, provide at least four rounds and not more than ten rounds of data that is not seasonally affected. Use consistent units. The spreadsheet contains several error checks, and a data entry error may cause "DATA ERR" or "DATE ERR" to be displayed. Dates that are not consecutive will show an error message and will not display the test results. The spreadsheet tests the data for both increasing and decreasing trends at both 80 percent and 90 percent confidence levels. If a declining trend is present at 80 percent but not at 90 percent, a site is still eligible for closure under Comm 46 and NR 746 provided that other conditions in those rules are met. If an increasing or decreasing trend is not present, an additional coefficient of variation test is used to test for stability, as proposed by Wiedemeier et al, 1999. For additional information, refer to the Interim Guidance on Natural Attenuation for Petroleum Releases, dated October 1999. Refer to the guidance for recommendations on data entry for non-detect values.

Site Name = Solutia WGK Site | BRRTS No. = | Well Number = 6D

Event Number	Sampling Date (most recent last)	Monochlorobiphenyl Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)	Concentration (blank if no data; Red if ND/2 used)
1	18-Aug-08	0.21					
2	5-Jun-09	0.29					
3	18-Aug-09	0.2					
4	13-Nov-09	0.3					
5	12-Feb-10	0.19					
6	14-May-10	0.33					
7							
8							
9							
10							
	Mann Kendall Statistic (S) =	3.0	0.0	0.0	0.0	0.0	0.0
	Number of Rounds (n) =	6	0	0	0	0	0
	Average =	0.25	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Standard Deviation =	0.060	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Coefficient of Variation(CV)=	0.238	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Error Check, Blank if No Errors Detected			n<4	n<4	n<4	n<4	n<4
Trend ≥ 80% Confidence Level		No Trend	n<4	n<4	n<4	n<4	n<4
Trend ≥ 90% Confidence Level		No Trend	n<4	n<4	n<4	n<4	n<4
Trend ≥ 95% Confidence Level		No Trend	n<4	n<4	n<4	n<4	n<4
Stability Test, If No Trend Exists at 80% Confidence Level		CV <= 1 STABLE	n<4 n<4	n<4 n<4	n<4 n<4	n<4 n<4	n<4 n<4

Data Entry By = PWS | Date = 22-Jun-10 | Checked By = WAN

Attachment C

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-1M

Well ID	Chemical	3rd Quarter 2008 Result	4th Quarter 2008 Result	1st Quarter 2009 Result	2nd Quarter 2009 Result	3rd Quarter 2009 Result	4th Quarter 2009 Result	1st Quarter 2010 Result	2nd Quarter 2010 Result
Date		8/22/2008	11/18/2008	2/27/2009	6/5/2009	8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		400.15	396.53	395.5	401.27	398.05	400.33	399.85	401.11
1M	Monochlorobiphenyl	0.38	0.26	0.16	0.21	0.27	0.27	0.2	0.08

Results in Red are non-detects. Assume non-detects are half of detection limit or half the smallest detected value, whichever is less.

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.080	0.380	0.229	0.235	0.190	0.270	0.083	0.007

1st Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.160	0.380	0.253	0.235	0.198	0.290	0.082	0.007

2nd Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.080	0.270	0.205	0.235	0.170	0.270	0.078	0.006

		1st Four Quarters Concentrations				2nd Four Quarters Concentrations			
		3rd Quarter 2008	4th Quarter 2008	1st Quarter 2009	2nd Quarter 2009	3rd Quarter 2009	4th Quarter 2009	1st Quarter 2010	2nd Quarter 2010
1M	Monochlorobiphenyl	0.38	0.26	0.16	0.21	0.27	0.27	0.2	0.08
	Rank (least to greatest)	8	5	2	4	6.5	6.5	3	1

Wilcoxon Rank-sum Test
(i.e., Mann-Whitney U Test)

Total observations, N = 8 Total Background, m = 4 Total Compliance, n = 4

$\alpha = 0.05$ (α_{05}), then $z_{cr} = 1.6449$ $\alpha = 0.10$ (α_{10}), then $z_{cr} = 1.2816$

1st Four Quarters -- Wilcoxon statistic, W = 19 2nd Four Quarters -- Wilcoxon statistic, W = 17

Expected Value of the Wilcoxon statistic = E(W)= 1/2*n*(N + 1) = 18

Assume 1st Four Quarters represent "Compliance Wells"

W for the 1st Four Quarters is greater than W for the 2nd Four Quarters and greater than E(W).
In other words, expect to see decrease in concentration between 1st and 2nd Four Quarters.

Std Dev. of the Wilcoxon statistic, W = SD(W) = sqrt(1/12*m*n*(N + 1)) = *3.46* **N/A** -- One set of tied values

If tied values

$$SD^*(W) = \sqrt{\frac{mn(N+1)}{12}\left(1 - \Sigma_{i=1}^{g} \frac{t_i^3 - t_i}{N^3 - N}\right)}$$ **3.44** Use this value since one set of tied values.

Where, g equals the number of different groups of tied observations and t_i represents the number of tied values in the ith group

Approx. z-score for the Wilcoxon rank-sum test Z = (W - E(W) - 1/2) / SD(W) = 0.1452

Is $Z > \alpha_{05}$? FALSE

Is $Z > \alpha_{10}$? FALSE

Hypothesis of equivalent background and compliance point distributions cannot be rejected, i.e., no significant change between 1st Four Quarters and 2nd Four Quarters. Therefore, concentrations appear to be STABLE from 1st Four Quarters to 2nd Four Quarters.

Student's T-Test

Evaluate normality of data using Shapiro-Wilk Normality Test

N = 8 then k = 4

Find b

$$b = \sum_{i=1}^{k} b_i = \sum_{i=1}^{k} a_{n-i+1}(x_{(n-i+1)} - x_{(i)})$$

Compute differences $[x_{(n-i+1)} - x_{(i)}]$ for each i = 1…n.

		From EPA Guidance (2009)		$b_{(i)}$
$x_{(8-1+1)} - x_{(1)}$	0.30	$a_{(8-1+1)}$	0.6052	0.1816
$x_{(8-2+1)} - x_{(2)}$	0.11	$a_{(8-2+1)}$	0.3164	0.0348
$x_{(8-3+1)} - x_{(3)}$	0.07	$a_{(8-3+1)}$	0.1743	0.0122
$x_{(8-4+1)} - x_{(4)}$	0.05	$a_{(8-4+1)}$	0.0561	0.0028
			b =	**0.2314**

Compute the Shapiro-Wilk test statistic, SW

$SW = (b/(s*\text{sqrt}(n-1)))^2 =$ 1.1468

Critical point of the Shapiro-Wilk test with n observations, sw_{cr} = 0.792 (From EPA Guidance, 2009)

$SW > sw_{cr}$? TRUE Data is normally distributed, two tails

Student's T-Test	0.173	Assume one tail and paired observations	
	0.345	Assume two tails and paired observations	
	0.246	Assume one tail and equal variance (homoscedastic)	
	0.246	Assume one tail and unequal variance (heteroscedastic)	
	0.493	**Assume two tails and equal variance (homoscedastic)**	**<<< Appears to be appropriate case**
	0.493	Assume two tails and unequal variance (heteroscedastic)	

Degrees of Freedom, d_f = 6

α-level critical points

$\alpha = 0.05\ (\alpha_{05}) = 1.943$	T-Test > α_{05}?	**FALSE**
$\alpha = 0.10\ (\alpha_{10}) = 1.440$	T-Test > α_{10}?	**FALSE**

T-statistic is less than the critical point, so insufficient evidence of a significant difference between 1st and 2nd Four Quarters at the 0.05 and 0.10 levels (95% and 90% confidence levels, respectively). Therefore, concentrations appear to be STABLE from 1st Four Quarters to 2nd Four Quarters.

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-2M

		3rd Quarter 2008	4th Quarter 2008	1st Quarter 2009	2nd Quarter 2009	3rd Quarter 2009	4th Quarter 2009	1st Quarter 2010	2nd Quarter 2010
Well ID	**Chemical**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
Date		8/22/2008	11/18/2008	2/27/2009	6/5/2009	8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		400.15	396.53	395.5	401.27	398.05	400.33	399.85	401.11
2M	Monochlorobiphenyl	4.3	2.5	2.9	3.6	3.1	2.7	2.4	1.2

Results in Red are non-detects. Assume non-detects are half of detection limit or half the smallest detected value, whichever is less.

min	max	mean	median	25%	75%	Std Dev (s)	Variance
1.200	4.300	2.838	2.800	2.475	3.225	0.851	0.725

1st Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
2.500	4.300	3.325	3.250	2.800	3.775	0.687	0.472

2nd Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
1.200	3.100	2.350	2.550	2.100	2.800	0.709	0.503

		1st Four Quarters Concentrations				**2nd Four Quarters Concentrations**			
		3rd Quarter 2008	**4th Quarter 2008**	**1st Quarter 2009**	**2nd Quarter 2009**	**3rd Quarter 2009**	**4th Quarter 2009**	**1st Quarter 2010**	**2nd Quarter 2010**
2M	Monochlorobiphenyl	4.3	2.5	2.9	3.6	3.1	2.7	2.4	1.2
	Rank (least to greatest)	8	3	5	7	6	4	2	1

Wilcoxon Rank-sum Test
(i.e., Mann-Whitney U Test)

Total observations, N = 8   Total Background, m = 4   Total Compliance, n = 4

$\alpha = 0.05$ (α_{05}), then $z_{cr} = 1.6449$ $\alpha = 0.10$ (α_{10}), then $z_{cr} = 1.2816$

1st Four Quarters -- Wilcoxon statistic, W = 23   2nd Four Quarters -- Wilcoxon statistic, W = 13

Expected Value of the Wilcoxon statistic = $E(W) = 1/2*n*(N + 1) =$ 18

Assume 1st Four Quarters represent "Compliance Wells"

W for the 1st Four Quarters is greater than W for the 2nd Four Quarters and greater than E(W).

In other words, expect to see decrease in concentration between 1st and 2nd Four Quarters.

Std Dev. of the Wilcoxon statistic, W = SD(W) = sqrt(1/12*m*n*(N + 1)) = **3.46** Use this value since no tied values.

If tied values

$$SD^*(W) = \sqrt{\frac{mn(N+1)}{12}\left(1 - \Sigma_{i=1}^{g} \frac{t_i^3 - t_i}{N^3 - N}\right)}$$ *3.44* **N/A** -- No tied values

Where, g equals the number of different groups of tied observations and t_i represents the number of tied values in the ith group

Approx. z-score for the Wilcoxon rank-sum test Z = (W - E(W) - 1/2) / SD(W) = 1.2990

Is $Z > \alpha_{05}$? FALSE

Is $Z > \alpha_{10}$? TRUE

Hypothesis of equivalent background and compliance point distributions cannot be rejected at the 0.05 level (95% confidence level).
However, equivalent background and compliance point distributions may exist at the 0.10 level (90% confidence level).
Therefore, concentrations appear to be Stable or Slightly Decreasing from 1st Four Quarters to 2nd Four Quarters.

Student's T-Test

Evaluate normality of data using Shapiro-Wilk Normality Test

N = 8 then k = 4

Find b

$$b = \sum_{i=1}^{k} b_i = \sum_{i=1}^{k} a_{n-i+1}(x_{(n-i+1)} - x_{(i)})$$

Compute differences $[x_{(n-i+1)} - x_{(i)}]$ for each i = 1…n.		From EPA Guidance (2009)		$b_{(i)}$
$x_{(8-1+1)} - x_{(1)}$	3.10	$a_{(8-1+1)}$	0.6052	1.8761
$x_{(8-2+1)} - x_{(2)}$	1.20	$a_{(8-2+1)}$	0.3164	0.3797
$x_{(8-3+1)} - x_{(3)}$	0.60	$a_{(8-3+1)}$	0.1743	0.1046
$x_{(8-4+1)} - x_{(4)}$	0.20	$a_{(8-4+1)}$	0.0561	0.0112
			b =	**2.3716**

Compute the Shapiro-Wilk test statistic, SW

SW = $(b/(s*\text{sqrt}(n-1)))^2$ = 1.7028

Critical point of the Shapiro-Wilk test with n observations, sw_{cr} = 0.792 (From EPA Guidance, 2009)

SW > sw_{cr}? TRUE Data is normally distributed, two tails

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-2M

Student's T-Test	0.088	Assume one tail and paired observations	
	0.177	Assume two tails and paired observations	
	0.069	Assume one tail and equal variance (homoscedastic)	
	0.069	Assume one tail and unequal variance (heteroscedastic)	
	0.138	**Assume two tails and equal variance (homoscedastic)**	**<<< Appears to be appropriate case**
	0.138	Assume two tails and unequal variance (heteroscedastic)	

Degrees of Freedom, d_f = 6

α-level critical points

$\alpha = 0.05\ (\alpha_{05}) = 1.943$	T-Test > α_{05}?	**FALSE**
$\alpha = 0.10\ (\alpha_{10}) = 1.440$	T-Test > α_{10}?	**FALSE**

T-statistic is less than the critical point, so insufficient evidence of a significant difference between 1st and 2nd Four Quarters at the 0.05 and 0.10 levels (95% and 90% confidence levels, respectively). Therefore, concentrations appear to be STABLE from 1st Four Quarters to 2nd Four Quarters.

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-3M

Well ID	Chemical	3rd Quarter 2008 Result	4th Quarter 2008 Result	1st Quarter 2009 Result	2nd Quarter 2009 Result	3rd Quarter 2009 Result	4th Quarter 2009 Result	1st Quarter 2010 Result	2nd Quarter 2010 Result
Date		8/22/2008	11/18/2008	2/27/2009	6/5/2009	8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		400.15	396.53	395.5	401.27	398.05	400.33	399.85	401.11
3M	Monochlorobiphenyl	1.3	0.71	1.4	1.3	0.85	0.85	0.87	0.82

Results in Red are non-detects. Assume non-detects are half of detection limit or half the smallest detected value, whichever is less.

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.710	1.400	1.013	0.860	0.843	1.300	0.254	0.065

1st Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.710	1.400	1.178	1.300	1.153	1.325	0.273	0.075

2nd Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.820	0.870	0.848	0.850	0.843	0.855	0.018	0.000

		1st Four Quarters Concentrations				2nd Four Quarters Concentrations			
		3rd Quarter 2008	4th Quarter 2008	1st Quarter 2009	2nd Quarter 2009	3rd Quarter 2009	4th Quarter 2009	1st Quarter 2010	2nd Quarter 2010
3M	Monochlorobiphenyl	1.3	0.71	0.69	1.3	0.85	0.85	0.87	0.82
	Rank (least to greatest)	6.5	1	8	6.5	3.5	3.5	5	2

Wilcoxon Rank-sum Test

(i.e., Mann-Whitney U Test) Total observations, N = 8 Total Background, m = 4 Total Compliance, n = 4

$\alpha = 0.05$ (α_{05}), then $z_{cr} = 1.6449$ $\alpha = 0.10$ (α_{10}), then $z_{cr} = 1.2816$

1st Four Quarters -- Wilcoxon statistic, W = 22 2nd Four Quarters -- Wilcoxon statistic, W = 14

Expected Value of the Wilcoxon statistic = E(W)= 1/2*n*(N + 1) = 18

Assume 1st Four Quarters represent "Compliance Wells"

W for the 1st Four Quarters is greater than W for the 2nd Four Quarters and greater than E(W).

In other words, expect to see decrease in concentration between 1st and 2nd Four Quarters.

Std Dev. of the Wilcoxon statistic, W = SD(W) = sqrt(1/12*m*n*(N + 1)) = *3.46* **N/A** -- Two sets of tied values

If tied values

$$SD^*(W) = \sqrt{\frac{mn(N+1)}{12}\left(1 - \Sigma_{i=1}^{g} \frac{t_i^3 - t_i}{N^3 - N}\right)}$$ **3.42** Use this value since two sets of tied values.

Where, g equals the number of different groups of tied observations and t_i represents the number of tied values in the ith group

Approx. z-score for the Wilcoxon rank-sum test Z = (W - E(W) - 1/2) / SD(W) = 1.0104

Is $Z > \alpha_{05}$? FALSE

Is $Z > \alpha_{10}$? FALSE

Hypothesis of equivalent background and compliance point distributions cannot be rejected, i.e., no significant change between 1st Four Quarters and 2nd Four Quarters.

Therefore, concentrations appear to be STABLE from 1st Four Quarters to 2nd Four Quarters.

Student's T-Test

Evaluate normality of data using Shapiro-Wilk Normality Test

N = 8 then k = 4

Find b

$$b = \sum_{i=1}^{k} b_i = \sum_{i=1}^{k} a_{n-i+1}(x_{(n-i+1)} - x_{(i)})$$

Compute differences $[x_{(n-i+1)} - x_{(i)}]$ for each i = 1…n.		From EPA Guidance (2009)		$b_{(i)}$
$x_{(8-1+1)} - x_{(1)}$	-0.02	$a_{(8-1+1)}$	0.6052	-0.0121
$x_{(8-2+1)} - x_{(2)}$	0.48	$a_{(8-2+1)}$	0.3164	0.1519
$x_{(8-3+1)} - x_{(3)}$	0.45	$a_{(8-3+1)}$	0.1743	0.0784
$x_{(8-4+1)} - x_{(4)}$	0.02	$a_{(8-4+1)}$	0.0561	0.0011
			b =	**0.2193**

Compute the Shapiro-Wilk test statistic, SW

$SW = (b/(s*\mathrm{sqrt}(n-1)))^2 =$ 0.0922

Critical point of the Shapiro-Wilk test with n observations, sw_{cr} = 0.792 (From EPA Guidance, 2009)

$SW > sw_{cr}$? FALSE Data is normally distributed, two tails

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-3M

Student's T-Test	0.230	Assume one tail and paired observations	
	0.461	Assume two tails and paired observations	
	0.207	Assume one tail and equal variance (homoscedastic)	
	0.222	Assume one tail and unequal variance (heteroscedastic)	
	0.413	Assume two tails and equal variance (homoscedastic)	
	0.444	**Assume two tails and unequal variance (heteroscedastic)**	**<<< Appears to be appropriate case**

Degrees of Freedom, d_f = 6

α-level critical points

$\alpha = 0.05\ (\alpha_{05}) = 1.943$	T-Test > α_{05}?	**FALSE**
$\alpha = 0.10\ (\alpha_{10}) = 1.440$	T-Test > α_{10}?	**FALSE**

T-statistic is less than the critical point, so insufficient evidence of a significant difference between 1st and 2nd Four Quarters at the 0.05 and 0.10 levels (95% and 90% confidence levels, respectively). Therefore, concentrations appear to be STABLE from 1st Four Quarters to 2nd Four Quarters.

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-3S - Monochlorobiphenyl

Well ID	Chemical	3rd Quarter 2008 Result	4th Quarter 2008 Result	1st Quarter 2009 Result	2nd Quarter 2009 Result	3rd Quarter 2009 Result	4th Quarter 2009 Result	1st Quarter 2010 Result	2nd Quarter 2010 Result
Date		8/22/2008	11/18/2008	2/27/2009	6/5/2009	8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		400.15	396.53	395.5	401.27	398.05	400.33	399.85	401.11
3S	Monochlorobiphenyl	0.26	0.24	0.67	0.047	0.34	1.8	0.0475	0.52

Results in Red are non-detects. Assume non-detects are half of detection limit or half the smallest detected value, whichever is less.

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.047	1.800	0.491	0.300	0.192	0.558	0.534	0.285

1st Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.047	0.670	0.304	0.250	0.192	0.363	0.227	0.052

2nd Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.048	1.800	0.677	0.430	0.267	0.840	0.670	0.449

		1st Four Quarters Concentrations				2nd Four Quarters Concentrations			
		3rd Quarter 2008	4th Quarter 2008	1st Quarter 2009	2nd Quarter 2009	3rd Quarter 2009	4th Quarter 2009	1st Quarter 2010	2nd Quarter 2010
3S	Monochlorobiphenyl	0.26	0.24	0.43	0.047	0.34	1.8	0.0475	0.52
	Rank (least to greatest)	4	3	6	1	5	8	2	7

Wilcoxon Rank-sum Test
(i.e., Mann-Whitney U Test)

Total observations, N = 8   Total Background, m = 4   Total Compliance, n = 4

$\alpha = 0.05$ (α_{05}), then z_{cr} = 1.6449 $\alpha = 0.10$ (α_{10}), then z_{cr} = 1.2816

1st Four Quarters -- Wilcoxon statistic, W = 14   2nd Four Quarters -- Wilcoxon statistic, W = 22

Expected Value of the Wilcoxon statistic = E(W)= 1/2*n*(N + 1) = 18

Assume 2nd Four Quarters represent "Compliance Wells"

W for the 2nd Four Quarters is greater than W for the 1st Four Quarters and greater than E(W).

In other words, expect to see increase in concentration between 1st and 2nd Four Quarters.

Std Dev. of the Wilcoxon statistic, W = SD(W) = sqrt(1/12*m*n*(N + 1)) = **3.46** Use this value since no tied values.

If tied values

$$SD^*(W) = \sqrt{\frac{mn(N+1)}{12}\left(1 - \Sigma_{i=1}^{g} \frac{t_i^3 - t_i}{N^3 - N}\right)}$$ *3.42* **N/A** -- No tied values

Where, g equals the number of different groups of tied observations and t_i represents the number of tied values in the ith group

Approx. z-score for the Wilcoxon rank-sum test Z = (W - E(W) - 1/2) / SD(W) = 1.0104

Is $Z > \alpha_{05}$? FALSE

Is $Z > \alpha_{10}$? FALSE

Hypothesis of equivalent background and compliance point distributions cannot be rejected, i.e., no significant change between 1st Four Quarters and 2nd Four Quarters.

Therefore, concentrations appear to be STABLE from 1st Four Quarters to 2nd Four Quarters.

Student's T-Test

Evaluate normality of data using Shapiro-Wilk Normality Test

N = 8 then k = 4

Find b

$$b = \sum_{i=1}^{k} b_i = \sum_{i=1}^{k} a_{n-i+1}(x_{(n-i+1)} - x_{(i)})$$

Compute differences $[x_{(n-i+1)} - x_{(i)}]$ for each i = 1…n.		From EPA Guidance (2009)		$b_{(i)}$
$x_{(8-1+1)} - x_{(1)}$	1.75	$a_{(8-1+1)}$	0.6052	1.0609
$x_{(8-2+1)} - x_{(2)}$	0.21	$a_{(8-2+1)}$	0.3164	0.0672
$x_{(8-3+1)} - x_{(3)}$	0.19	$a_{(8-3+1)}$	0.1743	0.0331
$x_{(8-4+1)} - x_{(4)}$	0.08	$a_{(8-4+1)}$	0.0561	0.0045
			b =	**1.1658**

Compute the Shapiro-Wilk test statistic, SW

$SW = (b/(s*sqrt(n-1)))^2 =$ 3.7691

Critical point of the Shapiro-Wilk test with n observations, sw_{cr} = 0.792 (From EPA Guidance, 2009)

$SW > sw_{cr}$? TRUE Data is normally distributed, two tails

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-3S - Monochlorobiphenyl

Student's T-Test	0.187	Assume one tail and paired observations	
	0.373	Assume two tails and paired observations	
	0.158	Assume one tail and equal variance (homoscedastic)	
	0.174	Assume one tail and unequal variance (heteroscedastic)	
	0.315	Assume two tails and equal variance (homoscedastic)	
	0.348	**Assume two tails and unequal variance (heteroscedastic)**	**<<< Appears to be appropriate case**

Degrees of Freedom, d_f = 6

α-level critical points

$\alpha = 0.05\ (\alpha_{05}) = 1.943$	T-Test > α_{05}?	**FALSE**
$\alpha = 0.10\ (\alpha_{10}) = 1.440$	T-Test > α_{10}?	**FALSE**

T-statistic is less than the critical point, so insufficient evidence of a significant difference between 1st and 2nd Four Quarters at the 0.05 and 0.10 levels (95% and 90% confidence levels, respectively). Therefore, concentrations appear to be STABLE from 1st Four Quarters to 2nd Four Quarters.

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-3S - Dichlorobiphenyl

Well ID	Chemical	3rd Quarter 2008 Result	4th Quarter 2008 Result	1st Quarter 2009 Result	2nd Quarter 2009 Result	3rd Quarter 2009 Result	4th Quarter 2009 Result	1st Quarter 2010 Result	2nd Quarter 2010 Result
Date		8/22/2008	11/18/2008	2/27/2009	6/5/2009	8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		400.15	396.53	395.5	401.27	398.05	400.33	399.85	401.11
3S	Dichlorobiphenyl	0.0485	0.05	0.12	0.047	0.047	0.23	0.0475	0.11

Results in Red are non-detects. Assume non-detects are half of detection limit or half the smallest detected value, whichever is less.

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.047	0.230	0.088	0.049	0.047	0.113	0.061	0.004

1st Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.047	0.120	0.066	0.049	0.048	0.068	0.031	0.001

2nd Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.047	0.230	0.109	0.079	0.047	0.140	0.075	0.006

		1st Four Quarters Concentrations				2nd Four Quarters Concentrations			
		3rd Quarter 2008	4th Quarter 2008	1st Quarter 2009	2nd Quarter 2009	3rd Quarter 2009	4th Quarter 2009	1st Quarter 2010	2nd Quarter 2010
3S	Dichlorobiphenyl	0.0485	0.05	0.12	0.047	0.047	0.23	0.0475	0.11
	Rank (least to greatest)	4	5	7	1.5	1.5	8	3	6

Wilcoxon Rank-sum Test
(i.e., Mann-Whitney U Test)

Total observations, N = 8 Total Background, m = 4 Total Compliance, n = 4

$\alpha = 0.05$ (α_{05}), then $z_{cr} = 1.6449$ $\alpha = 0.10$ (α_{10}), then $z_{cr} = 1.2816$

1st Four Quarters -- Wilcoxon statistic, W = 17.5 2nd Four Quarters -- Wilcoxon statistic, W = 18.5

Expected Value of the Wilcoxon statistic = $E(W)= 1/2*n*(N + 1) =$ 18

Assume 2nd Four Quarters represent "Compliance Wells"

W for the 2nd Four Quarters is greater than W for the 1st Four Quarters and greater than E(W).
In other words, expect to see increase in concentration between 1st and 2nd Four Quarters.

Std Dev. of the Wilcoxon statistic, W = SD(W) = sqrt(1/12*m*n*(N + 1)) = *3.46* **N/A** -- One set of tied values

If tied values

$$SD^*(W) = \sqrt{\frac{mn(N+1)}{12}\left(1 - \Sigma_{i=1}^{g} \frac{t_i^3 - t_i}{N^3 - N}\right)}$$ **3.44** Use this value since one set of tied values.

Where, g equals the number of different groups of tied observations and t_i represents the number of tied values in the ith group

Approx. z-score for the Wilcoxon rank-sum test Z = (W - E(W) - 1/2) / SD(W) = 0.0000

Is $Z > \alpha_{05}$? FALSE

Is $Z > \alpha_{10}$? FALSE

Hypothesis of equivalent background and compliance point distributions cannot be rejected,
i.e., no significant change between 1st Four Quarters and 2nd Four Quarters.
Therefore, concentrations appear to be STABLE from 1st Four Quarters to 2nd Four Quarters.

Student's T-Test

Evaluate normality of data using Shapiro-Wilk Normality Test

N = 8 then k = 4

Find b

$$b = \sum_{i=1}^{k} b_i = \sum_{i=1}^{k} a_{n-i+1}(x_{(n-i+1)} - x_{(i)})$$

Compute differences $[x_{(n-i+1)} - x_{(i)}]$ for each i = 1…n.		From EPA Guidance (2009)		$b_{(i)}$
$x_{(8-1+1)} - x_{(1)}$	0.18	$a_{(8-1+1)}$	0.6052	0.1108
$x_{(8-2+1)} - x_{(2)}$	0.07	$a_{(8-2+1)}$	0.3164	0.0231
$x_{(8-3+1)} - x_{(3)}$	0.06	$a_{(8-3+1)}$	0.1743	0.0109
$x_{(8-4+1)} - x_{(4)}$	0.00	$a_{(8-4+1)}$	0.0561	0.0001
			b =	**0.1448**

Compute the Shapiro-Wilk test statistic, SW

$SW = (b/(s*\mathrm{sqrt}(n-1)))^2 =$ 3.1223

Critical point of the Shapiro-Wilk test with n observations, sw_{cr} = 0.792 (From EPA Guidance, 2009)

$SW > sw_{cr}$? TRUE Data is normally distributed, two tails

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-3S - Dichlorobiphenyl

Student's T-Test	0.244	Assume one tail and paired observations	
	0.488	Assume two tails and paired observations	
	0.200	Assume one tail and equal variance (homoscedastic)	
	0.208	Assume one tail and unequal variance (heteroscedastic)	
	0.400	Assume two tails and equal variance (homoscedastic)	
	0.416	**Assume two tails and unequal variance (heteroscedastic)**	**<<< Appears to be appropriate case**

Degrees of Freedom, d_f = 6

α-level critical points

$\alpha = 0.05\ (\alpha_{05}) = 1.943$	T-Test > α_{05}?	**FALSE**
$\alpha = 0.10\ (\alpha_{10}) = 1.440$	T-Test > α_{10}?	**FALSE**

T-statistic is less than the critical point, so insufficient evidence of a significant difference between 1st and 2nd Four Quarters at the 0.05 and 0.10 levels (95% and 90% confidence levels, respectively). Therefore, concentrations appear to be STABLE from 1st Four Quarters to 2nd Four Quarters.

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-4D - Monochlorobiphenyl

Well ID	Chemical	3rd Quarter 2008 Result	4th Quarter 2008 Result	1st Quarter 2009 Result	2nd Quarter 2009 Result	3rd Quarter 2009 Result	4th Quarter 2009 Result	1st Quarter 2010 Result	2nd Quarter 2010 Result
Date		8/22/2008	11/18/2008	2/27/2009	6/5/2009	8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		400.15	396.53	395.5	401.27	398.05	400.33	399.85	401.11
4D	Monochlorobiphenyl	NA	0.15	0.2	0.22	0.2	0.27	0.26	0.31

Results in Red are non-detects. Assume non-detects are half of detection limit or half the smallest detected value, whichever is less.

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.150	0.310	0.230	0.220	0.200	0.265	0.050	0.002

1st Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.150	0.220	0.190	0.200	0.175	0.210	0.086	0.001

2nd Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.200	0.310	0.260	0.265	0.245	0.280	0.039	0.002

		1st Four Quarters Concentrations				2nd Four Quarters Concentrations			
		3rd Quarter 2008	4th Quarter 2008	1st Quarter 2009	2nd Quarter 2009	3rd Quarter 2009	4th Quarter 2009	1st Quarter 2010	2nd Quarter 2010
4D	Monochlorobiphenyl	NA	0.15	0.2	0.22	0.2	0.27	0.26	0.31
	Rank (least to greatest)		1	2.5	4	2.5	6	5	7

Wilcoxon Rank-sum Test

(i.e., Mann-Whitney U Test) Total observations, N = 7 Total Background, m = 3 Total Compliance, n = 4

$\alpha = 0.05$ (α_{05}), then $z_{cr} = 1.6449$ $\alpha = 0.10$ (α_{10}), then $z_{cr} = 1.2816$

Not enough observations to perform Wilcoxon Rank-sum Test -- Need minimum of four observations in each set.

Student's T-Test

Evaluate normality of data using Shapiro-Wilk Normality Test

N = 7 then k = 3

Find b

$$b=\sum_{i=1}^{k} b_i = \sum_{i=1}^{k} a_{n-i+1}(x_{(n-i+1)} - x_{(i)})$$

Compute differences $[x_{(n-i+1)} - x_{(i)}]$ for each i = 1…n.		From EPA Guidance (2009)		$b_{(i)}$
$x_{(8-1+1)} - x_{(1)}$	0.16	$a_{(8-1+1)}$	0.6052	0.0968
$x_{(8-2+1)} - x_{(2)}$	0.07	$a_{(8-2+1)}$	0.3164	0.0221
$x_{(8-3+1)} - x_{(3)}$	0.06	$a_{(8-3+1)}$	0.1743	0.0105
			b =	**0.1294**

Compute the Shapiro-Wilk test statistic, SW

$SW = (b/(s*sqrt(n-1)))^2 =$ 1.1364

Critical point of the Shapiro-Wilk test with n observations, sw_{cr} = 0.792 (From EPA Guidance, 2009)

SW > sw_{cr}? TRUE Data is normally distributed, two tails

Student's T-Test		
	0.040	Assume one tail and equal variance (homoscedastic)
	0.037	Assume one tail and unequal variance (heteroscedastic)
	0.081	**Assume two tails and equal variance (homoscedastic)** **<<< Appears to be appropriate case**
	0.073	Assume two tails and unequal variance (heteroscedastic)

Degrees of Freedom, d_f = 5

α-level critical points

$\alpha = 0.05\ (\alpha_{05}) = 1.943$ T-Test > α_{05}? **FALSE**

$\alpha = 0.10\ (\alpha_{10}) = 1.440$ T-Test > α_{10}? **FALSE**

T-statistic is less than the critical point, so insufficient evidence of a significant difference between 1st and 2nd Four Quarters at the 0.05 and 0.10 levels (95% and 90% confidence levels, respectively). Therefore, concentrations appear to be STABLE from 1st Four Quarters to 2nd Four Quarters.

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-4D - Dichlorobiphenyl

		3rd Quarter 2008	4th Quarter 2008	1st Quarter 2009	2nd Quarter 2009	3rd Quarter 2009	4th Quarter 2009	1st Quarter 2010	2nd Quarter 2010
Well ID	**Chemical**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
Date		8/22/2008	11/18/2008	2/27/2009	6/5/2009	8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		400.15	396.53	395.5	401.27	398.05	400.33	399.85	401.11
4D	Dichlorobiphenyl	NA	0.12	0.21	0.37	0.17	0.34	0.28	0.41

Results in Red are non-detects. Assume non-detects are half of detection limit or half the smallest detected value, whichever is less.

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.120	0.410	0.271	0.280	0.190	0.355	0.100	0.010

1st Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.120	0.370	0.233	0.210	0.165	0.290	0.103	0.011

2nd Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.170	0.410	0.300	0.310	0.253	0.358	0.088	0.008

		1st Four Quarters Concentrations				2nd Four Quarters Concentrations			
		3rd Quarter 2008	4th Quarter 2008	1st Quarter 2009	2nd Quarter 2009	3rd Quarter 2009	4th Quarter 2009	1st Quarter 2010	2nd Quarter 2010
4D	Dichlorobiphenyl	NA	0.12	0.21	0.37	0.17	0.34	0.28	0.41
	Rank (least to greatest)		1	3	6	2	5	4	7

Wilcoxon Rank-sum Test

(i.e., Mann-Whitney U Test) Total observations, N = 7 Total Background, m = 3 Total Compliance, n = 4

$\alpha = 0.05$ (α_{05}), then $z_{cr} = 1.6449$ $\alpha = 0.10$ (α_{10}), then $z_{cr} = 1.2816$

Not enough observations to perform Wilcoxon Rank-sum Test -- Need minimum of four observations in each set.

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-4D - Dichlorobiphenyl

Student's T-Test

Evaluate normality of data using Shapiro-Wilk Normality Test

N = 7 then k = 3

Find b

$$b=\sum_{i=1}^{k} b_i = \sum_{i=1}^{k} a_{n-i+1}(x_{(n-i+1)} - x_{(i)})$$

Compute differences $[x_{(n-i+1)} - x_{(i)}]$ for each i = 1…n.

		From EPA Guidance (2009)		$b_{(i)}$
$x_{(8-1+1)} - x_{(1)}$	0.29	$a_{(8-1+1)}$	0.6052	0.1755
$x_{(8-2+1)} - x_{(2)}$	0.20	$a_{(8-2+1)}$	0.3164	0.0633
$x_{(8-3+1)} - x_{(3)}$	0.13	$a_{(8-3+1)}$	0.1743	0.0227
			b =	**0.2614**

Compute the Shapiro-Wilk test statistic, SW

$SW = (b/(s*sqrt(n-1)))^2 =$ 1.1282

Critical point of the Shapiro-Wilk test with n observations, sw_{cr} = 0.792 (From EPA Guidance, 2009)

$SW > sw_{cr}$? TRUE Data is normally distributed, two tails

Student's T-Test

0.236	Assume one tail and equal variance (homoscedastic)
0.249	Assume one tail and unequal variance (heteroscedastic)
0.472	**Assume two tails and equal variance (homoscedastic)** **<<< Appears to be appropriate case**
0.498	Assume two tails and unequal variance (heteroscedastic)

Degrees of Freedom, d_f = 5

α-level critical points

$\alpha = 0.05$ (α_{05}) = 1.943 T-Test > α_{05}? **FALSE**

$\alpha = 0.10$ (α_{10}) = 1.440 T-Test > α_{10}? **FALSE**

T-statistic is less than the critical point, so insufficient evidence of a significant difference between 1st and 2nd Four Quarters at the 0.05 and 0.10 levels (95% and 90% confidence levels, respectively). Therefore, concentrations appear to be STABLE from 1st Four Quarters to 2nd Four Quarters.

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-6D

Well ID	Chemical	3rd Quarter 2008 Result	4th Quarter 2008 Result	1st Quarter 2009 Result	2nd Quarter 2009 Result	3rd Quarter 2009 Result	4th Quarter 2009 Result	1st Quarter 2010 Result	2nd Quarter 2010 Result
Date		8/22/2008	11/18/2008	2/27/2009	6/5/2009	8/18/2009	11/13/2009	2/12/2010	5/14/2010
Water Level		400.15	396.53	395.5	401.27	398.05	400.33	399.85	401.11
6D	Monochlorobiphenyl	0.21	0.43	0.32	0.29	0.2	0.3	0.19	0.33

Results in Red are non-detects. Assume non-detects are half of detection limit or half the smallest detected value, whichever is less.

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.190	0.430	0.284	0.295	0.208	0.323	0.076	0.006

1st Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.210	0.430	0.313	0.305	0.270	0.348	0.079	0.006

2nd Four Quarters

min	max	mean	median	25%	75%	Std Dev (s)	Variance
0.190	0.330	0.255	0.250	0.198	0.308	0.061	0.004

		1st Four Quarters Concentrations				2nd Four Quarters Concentrations			
		3rd Quarter 2008	4th Quarter 2008	1st Quarter 2009	2nd Quarter 2009	3rd Quarter 2009	4th Quarter 2009	1st Quarter 2010	2nd Quarter 2010
6D	Monochlorobiphenyl	0.21	0.43	0.32	0.29	0.2	0.3	0.19	0.33
	Rank (least to greatest)	3	8	6	4	2	5	1	7

Wilcoxon Rank-sum Test

(i.e., Mann-Whitney U Test)

Total observations, N = 8   Total Background, m = 4   Total Compliance, n = 4

$\alpha = 0.05$ (α_{05}), then $z_{cr} = 1.6449$ $\alpha = 0.10$ (α_{10}), then $z_{cr} = 1.2816$

1st Four Quarters -- Wilcoxon statistic, W = 21   2nd Four Quarters -- Wilcoxon statistic, W = 15

Expected Value of the Wilcoxon statistic = $E(W) = 1/2 \cdot n \cdot (N + 1)$ = 18

Assume 1st Four Quarters represent "Compliance Wells"

W for the 1st Four Quarters is greater than W for the 2nd Four Quarters and greater than E(W).

In other words, expect to see decrease in concentration between 1st and 2nd Four Quarters.

Std Dev. of the Wilcoxon statistic, W = SD(W) = sqrt(1/12*m*n*(N + 1)) = **3.46** Use this value since no tied values.

If tied values

$$SD^*(W) = \sqrt{\frac{mn(N+1)}{12}\left(1 - \Sigma_{i=1}^{g} \frac{t_i^3 - t_i}{N^3 - N}\right)}$$ *3.44* **N/A** -- No tied values

Where, g equals the number of different groups of tied observations and t_i represents the number of tied values in the ith group

Approx. z-score for the Wilcoxon rank-sum test Z = (W - E(W) - 1/2) / SD(W) = 0.7217

Is $Z > \alpha_{05}$? FALSE

Is $Z > \alpha_{10}$? FALSE

Hypothesis of equivalent background and compliance point distributions cannot be rejected, i.e., no significant change between 1st Four Quarters and 2nd Four Quarters.
Therefore, concentrations appear to be STABLE from 1st Four Quarters to 2nd Four Quarters.

Student's T-Test

Evaluate normality of data using Shapiro-Wilk Normality Test

N = 8 then k = 4

Find b

$$b = \sum_{i=1}^{k} b_i = \sum_{i=1}^{k} a_{n-i+1}(x_{(n-i+1)} - x_{(i)})$$

Compute differences $[x_{(n-i+1)} - x_{(i)}]$ for each i = 1…n.		From EPA Guidance (2009)		$b_{(i)}$
$x_{(8-1+1)} - x_{(1)}$	0.24	$a_{(8-1+1)}$	0.6052	0.1452
$x_{(8-2+1)} - x_{(2)}$	0.13	$a_{(8-2+1)}$	0.3164	0.0411
$x_{(8-3+1)} - x_{(3)}$	0.11	$a_{(8-3+1)}$	0.1743	0.0192
$x_{(8-4+1)} - x_{(4)}$	0.01	$a_{(8-4+1)}$	0.0561	0.0006
			b =	**0.2061**

Compute the Shapiro-Wilk test statistic, SW

SW = $(b/(s*\text{sqrt}(n-1)))^2$ = 0.9759

Critical point of the Shapiro-Wilk test with n observations, sw_{cr} = 0.792 (From EPA Guidance, 2009)

SW > sw_{cr}? TRUE Data is normally distributed, two tails

ATTACHMENT C
Mann-Whitney and T-Test Analyses
PCB Data 3Q08 through 2Q10
Monitoring Well PMA-MW-6D

Student's T-Test	0.137	Assume one tail and paired observations	
	0.274	Assume two tails and paired observations	
	0.178	Assume one tail and equal variance (homoscedastic)	
	0.179	Assume one tail and unequal variance (heteroscedastic)	
	0.356	Assume two tails and equal variance (homoscedastic)	
	0.359	**Assume two tails and unequal variance (heteroscedastic)**	**<<< Appears to be appropriate case**

Degrees of Freedom, d_f = 6

α-level critical points

$\alpha = 0.05\ (\alpha_{05}) = 1.943$	T-Test > α_{05}?	**FALSE**
$\alpha = 0.10\ (\alpha_{10}) = 1.440$	T-Test > α_{10}?	**FALSE**

T-statistic is less than the critical point, so insufficient evidence of a significant difference between 1st and 2nd Four Quarters at the 0.05 and 0.10 levels (95% and 90% confidence levels, respectively). Therefore, concentrations appear to be STABLE from 1st Four Quarters to 2nd Four Quarters.